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Contracts for Land Retirement under Asymmetric Information

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Abstract

A land retirement policy whereby land is taken out of agriculture and converted to natural vegetation or forestry has the potential to reduce environmental damage related to dryland salinity in Western Australia. This paper uses some recent results in the theory of directional distance functions (Chambers and Fare, 2004) to analyse alternative policy designs for a land retirement scheme. The results indicate that a fixed price scheme is inefficient compared with a first-best solution, but performs adequately. A scheme requiring a fixed proportion of area retired by all producers is inefficient. A separating solution, based on mechanism design, gives a small but siginificant increase in welfare compared to a fixed price scheme.

Key words: Agri-environmental policy, distance functions, efficiency, mechanism design

JEL classifications: Q12

1. Introduction

Land retirement policies, such as the EU set-aside scheme and CRP in the US, where a regulator aims to retire a proportion of the agricultural land in a region to achieve environmental objectives are increasingly important policy instruments. The issue addressed here is how should a land retirement scheme be designed when there is an asymmetry of information between the regulator and farmers. Chambers, (1987, 2002b) addresses the general problem of asymmetric information in agricultural policy using mechanism design. Mechanism design has also been proposed as an approach to agri-environmental policy (Wu and Babcock, 1996; Moxey, *et al.,* 1998; Bontems, *et al.,* 2005) and land retirement policy (Smith, 1995; Bourgeon *et al.,* 1995).

Despite a large number of theoretical models based on mechanism design the number of empirical applications has been small. Realistic applications are to be found in Smith (1995) who analyses a land retirement scheme by regions in the US; Bourgeon *et al.* (1995) apply mechanism design to the EU Set-aside scheme; and Bontems *et al.* (2005) design an optimal non-linear production tax/subsidy to address non-point source pollution. The reason for lack of applications is that they must resolve difficult empirical issues related to defining compliance cost functions and how they vary across farms when the farm population are heterogeneous. Firm type in most theoretical models is a single parameter which measures technical efficiency. In practice a number of other unobservable variables determine compliance cost including endowments of fixed factors of production, and allocative efficiency. The theoretical models developed in this paper are applied for a sample of farms in the Greater Southern region of Western Australia for the crop year 1999.

The remainder of the paper is organised as follows. Section 2 presents a theoretical model of the regulator's problem. Section 3 presents the approach to empirical modelling. Section 4 presents results and Section 5 concludes.

2. Regulation Model

A regulator, who acts as a Stackelberg leader (Laffont and Tirole, 1993, p56) sets up a scheme to retire land to maximise welfare. Farm profit, for allocatively efficient farms, is given by the restricted profit function $\pi(p, w, a^h, \bar{x}^h, \theta^h)$ where *p* and *w* are vectors of output and input prices, a^h is hectares farmed subject to fixed inputs other than land $\bar{x}^h$. Farm type is represented by technical efficiency θ^h , land area and endowment of fixed resources. The reservation profit is $\pi_0^h = \pi_0(p, w, a_0^h, \bar{x}^h, \theta^h)$ where a_0^h is the initial land area. The environmental benefit associated with crop land retirement is captured by $v > 0$.

Following Laffont and Tirole (1993, p56), the welfare function is:

$$\underset{\alpha^h, b^h}{Maximize} \sum_h \{v\alpha^h a_0^h - (\pi_0^h - \pi(p, w, a^h, \bar{x}^h, \theta^h)) - \lambda b^h \alpha^h a_0^h \} \qquad (1)$$

where welfare is maximised with respect to the transfer payment per hectare b^h and the proportion of land retired α^h . The welfare function comprise three components: the first gives the environmental benefit of land retirement, the second gives the compliance cost as the difference between the reservation profit and profit with land retirement and the third gives taxpayer cost as the transfer payment per hectare weighted by the shadow price of public funds, λ. This welfare function simplifies to:

$$\underset{\alpha^h, b^h}{Maximize} \sum_h \{\pi(p, w, a^h, \bar{x}^h, \theta^h) - \lambda b^h \alpha^h a_0^h\} \qquad (2)$$

by assuming the scheme retires a fixed total area and noting that the reservation profit is constant and can be dropped from the welfare function.

For first-best (Policy 1a), by assuming that firms are allocatively efficient, (2) is maximised subject to an individual rationality constraint

$$\pi_0^h \leq \pi(p, w, a^h, \bar{x}^h, \theta^h) + b^h \alpha^h a_0^h \qquad \forall h \qquad (3)$$

and a land retirement constraint:

$$\sum_h \alpha^h a_0^h = \tau \sum_h a_0^h \, . \qquad (4)$$

where the sum of land retired ($r^h = \alpha^h a_0^h$) by individual farms equals the target proportion τ of the total area. Each farm is offered an individual contract which specifies the proportion of the base area to be retired and the transfer payment per hectare.

Policy 1b is where farms are assumed to take decisions based vectors of farm specific 'wrong prices', p^h, w^h. As for Policy 1b each farm is offered individual contracts.

A fixed price scheme (Policy 2) offers all farms a fixed price per hectare $\bar{b}$ for land retired and allows the farms to decide on the area retired. Policy 3 offers a fixed price and fixed area scheme and includes constraint (4) and

$$r^h = \tau a_0^h \qquad \forall h \qquad (5)$$

where, all producers are constrained to retire a fixed proportion of their land. This scheme is equivalent to the EU set-aside scheme.

Policy 3 and 4 are pooling policies where there is no differentiation between farm types. Policy 1 offers separate contracts to each farmer, but may not be applicable where farms self-select A separating solution, if it is optimal, specifies a menu of contracts which require producers to retire different proportions of the land area in exchange for different rates of payment per ha. Policy 4 is an adaptation of Policy 1 and includes incentive compatibility constraints, which ensures efficient self selection.

$$\pi(p, w, \alpha^h a_0^h, \bar{x}^h, \theta^h) + b^h \alpha^h a_0^h \geq \pi(p, w, \alpha^k a_0^h, \bar{x}^h, \theta^h) + b^k \alpha^k a_0^h \qquad h,k \in H; \;\; h \neq k. \qquad (6)$$

Thus each firm identified in the population as a 'type' and has a policy given by $\{b^h, \alpha^h\}$. The left hand side of (6) gives the producer's profit of selecting the contract intended for type *h*. The right hand side gives the profit derived by type *h* selecting the contract intended for type *k.*

3. Estimating Compliance Costs

A Directional output distance function (Chambers, 2002) is estimated to measure the technical and allocative efficiency of farms. The output distance function allows maximum expansion of the output in a specified direction and is defined as follows: firm *h* produce a vector of outputs $y \in \Re_+^m$ using a vector of inputs $y \in \Re_+^n$. Technology is defined as a set:

$$T \subset \Re_+^n \times \Re_+^m : T = \{(x \in \Re_+^n, \Re_+^m) : \text{x can produce y}\}$$

The technology, *T*, satisfies the regularity conditions of no free lunch, is closed and convex, and has free disposability of inputs and outputs (Chambers, 2002). The output distance function is defined as follows:

$$\vec{D}_o(x, y; g_y) = \max\left\{\beta \in R : (y + \beta g_y) \in T\right\}, g_y \in R_+^m, (0, m) \neq (0^n, 0^m)$$

The firms operating on the frontier, where the value of the output distance function is zero, indicates that no further output expansion in the direction is feasible. Firms operating below the frontier are inefficient and the output distance measures the inefficiency of these firms.

The directional output distance function is a complete functional representation of the technology in that:

$$\vec{D}_o(x, y; g_y) \geq 0 \text{ if and only if } y \in T \qquad (7)$$

Where (7) implies that x can produce y if and only the distance function is nonnegative. In addition it is assumed that the output distance function satisfies the translation property so that:

$$\vec{D}_o(x, y + \theta g_y; g_y) = \vec{D}_o(x, y; g_y) - \theta, \qquad \theta \in R \qquad (8)$$

3.1. The Technical and Allocative Efficiency

Chambers and Fare (2004), establish the determination of technical and allocative efficiency for a distance function where the translation property holds. Their approach is based on Nerlove (1965) and states that an allocatively efficient firm solves the following profit maximization problem given technical efficiency θ.

$$\pi_0 = \sup\left\{ py - wx : (\vec{D}_o x, y, g_y) \le \theta \right\} = \sup\left\{ py - wx : \vec{D}_o(x, y + \theta g_y, g_y) \le 0 \right\}$$
$$= \theta p g_y + \pi(p, w) \quad (9)$$

which follows from the translation property (8). Equation (9) is in a *normalized* form by dividing through by pg_y to give:

$$\hat{\pi}_0 = \pi(\hat{p}, \hat{w}) + \theta$$

For the directional vector adopted here pg_y is the sum of output prices. Chambers and Fare (2004) define the difference between normalized maximal profit and normalized observed profit $\pi(\hat{p}, \hat{w}) - \hat{\pi}_0$ as Nerlovian profit efficiency. Nerlovian efficiency can be decomposed into allocative and technical efficiency using the approach of Lau and Yotopolous (1971) who assume that each firm perceive the 'wrong' price vectors p^h and w^h when taking input and output decisions.

$$\sup\left\{ p^h y - w^h x : (\vec{D}_0 x, y, g_y) \le \theta \right\} = \sup\left\{ p^h y - w^h x : \vec{D}_0 (x, y - \theta g_y; g_y) \le 0 \right\}$$
$$= \theta p^h g_y + \pi(p^h, w^h)$$

Assuming that the profit function is differentiable we obtain:

$$y(p^h, w^h, \theta) = \theta g_y + \Delta_p \pi(p^h, w^h)$$

$$x(p^h, w^h) = -\Delta_w \pi(p^h, w^h)$$

by Hotelling's Lemma. The observed profit with allocative inefficiency is

$$\pi_0^{ai} = \theta p g_y + p y(p^h, w^h, \theta) - w x(p^h, w^h)$$

If we normalize by pg_y, add the normalised maximal profit to both sides, and rearrange to give:

$$\pi(\hat{p}, \hat{w}) - \hat{\pi}_0^{ai} = \left\{ \pi(\hat{p}, \hat{w}) - \hat{p} y(p^h, w^h, \theta) - \hat{w} x(p^h, w^h) \right\} - \theta$$

The first term in brackets gives allocative efficiency as the difference between normalised profit and the profit at the outputs and inputs for the 'wrong' prices calculated using normalised prices.

Relating the conditions for profit maximization to the distance function gives the following first order conditions for an interior solution

$$p^h = -\Delta_y \vec{D}_o(x, y; g_y) p^h g_y \tag{10}$$

$$w^h = \Delta_x \vec{D}_o(x, y; g_y) p^h g_y \tag{11}$$

These first-order conditions are employed in the empirical regulation model analysis.

3.2 Functional Form

Ideally, the functional form for the distance function must satisfy two requirements, first it should be flexible, and second it should satisfy the translation property (8). This narrows the choice of tractable output distance functions to the quadratic form proposed by Chambers (1998):

$$\vec{D}_o(x^h, y^h; g_y) = \alpha_0 + \sum_{i=1}^{n} \alpha_i x_i^h + \frac{1}{2}\sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} x_i^h x_j^h + \frac{1}{2}\sum_{k=1}^{m} \sum_{l=1}^{m} \beta_{kj} y_k^h y_l^h + \sum_{i=1}^{n} b_k y_k^h + \frac{1}{2}\sum_{i=1}^{n} \sum_{k=1}^{n} \gamma_{ij} x_i^h y_k^h \tag{12}$$

Following Färe *et al.* (2001) and Aigner and Chu (1968) the output distance function (12) is estimated using linear programming. Where the parameters $\alpha_{0,,}$ $\alpha_{i,,}$ $\alpha_{ij,}$ $\beta_{kl,}$ b_k and γ_{ik} are selected to

$$\text{minimize } \sum_h \vec{D}_o(x_0^h, y_0^h; g_y) \tag{13a}$$

subject to

$$\vec{D}_o(x_0^h, y_0^h; g_y) \geq 0, \qquad \forall h \tag{13b}$$

$$\Delta_y \vec{D}_o(x_0^h, y_0^h; g_y) \leq 0, \qquad \forall h \tag{13c}$$

$$\Delta_x \vec{D}(x_0^h, y_0^h; g_y) \geq 0, \qquad \forall h \tag{13d}$$

where y_0^h and x_0^h give the observed input and output use where land is included in the input vector.

The output distance function inherits its properties from the output possibility set and to ensure functional form in (12) satisfy these properties, the minimisation problem in (13a) is solved subject to the following restrictions: (13b) constrains each firm to produce on or below the production frontier. Restrictions (13c) and (13d) ensure free disposability of inputs and outputs.

The following parameter restrictions ensure the output distance function satisfies the translation property (Chambers, 1998):

$$\alpha_{ij} = \alpha_{ji} \text{ and } \beta_{kl} = \beta_{lk.};\ \sum_{k=1}^{m} b_k = -1;\ \ \sum_{l=1}^{m} \beta_{kj} = 0,\ \ k = 1,.....,m; \sum_{k=1}^{m} \gamma_{kl} = 0,\ \ i = 1,....n$$

If the output set is assumed to be convex then the distance function is concave in outputs (Chambers, 2002). The curvature restriction is imposed using Lau's (1978) Cholesky decomposition method to ensure the Hessian matrix *H for* the distance function is negative semi-definite. The approach requires that the Hessian is given by

$$H = LDL'$$

where D a diagonal matrix of Cholesky values and L is a lower triangular matrix. For the distance function (12) weak concavity is imposed by reparametrizing the parameters and ensured the Cholesky values are constrained to be non-positive. The advantage of the quadratic functional form is that the Hessian matrix is parametric, thus global concavity can be imposed on the estimated distance function (Chambers, 1989).

3.3 Empirical Regulation Model

The profit function is not derived explicitly in this analysis; instead profit depends upon finding the maximum profit which is achievable given the firm's fixed input constraints and technical efficiency. Policy 1 involves solving the following nonlinear programming problem:

$$\underset{\alpha^h, b^h}{Maximize} \sum_h \{\pi^h - \lambda b^h \alpha^h a_0^h\} \tag{14a}$$

subject to

$$\vec{D}_o^*(x^h, y^h; g_y) \geq \theta^h, \qquad \forall h \tag{14b}$$

$$\Delta_y \vec{D}_o^*(x^h, y^h; g_y) \leq 0, \qquad \forall h \tag{14c}$$

$$\Delta_x \vec{D}_o^*(x^h, y^h; g_y) \geq 0, \qquad \forall h \tag{14d}$$

$$\pi^h = py^h - wx^h \qquad \forall h \tag{14e}$$

$$r^h = (a_0^h - a^h) \qquad \forall h \tag{14f}$$

$$\sum_h r^h = \tau \sum_h (a_0^h) \qquad \forall h \tag{14g}$$

$$a^h \leq a_0^h \qquad \forall h \tag{14h}$$

$$(\pi_0^h - \pi^h) - b^h r^h \geq 0 \qquad \forall h \tag{14i}$$

That is, the regulator's objective function is maximised, subject to a series of constraints that derive from the estimated distance function, $\vec{D}_o^*(x^h, y^h; g_y)$ that is (14b) the firm's efficiency is not increasing, the solution is at a point in the technology set where the output does not increase the distance and inputs do not reduce the distance. Equation (14e) gives the profit after land retirement. A land retirement variable r^h is defined by (14f). Equation (14g) is a land retirement constraint which specifies that a proportion of the original area τ is retired. Equation (14h) ensures that the crop area is reduced. Equation (14i) is an individual rationality constraint.

Policy 1b can be assessed assuming allocative inefficiency, by taking the shadow prices of outputs p^h and inputs w^h measured at the firms current input and output mix and forming the constraints:

$$\mathbf{p}^h = \Delta_y \vec{D}_o^*(\mathbf{x}^h, \mathbf{y}^h; \mathbf{g}_y) p^h g_y$$

$$\mathbf{w}^h = \Delta_x \vec{D}_o^*(\mathbf{x}^h, \mathbf{y}^h; \mathbf{g}_y) p^h g_y$$

For the fixed price policy, Policy 2, the profit maximisation problem is identical except that the individual farm transfers b^h are replaced by a fixed transfer payment $\bar{b}$ per hectare, farms are allowed to select the area of their farm retired.

Policy 3 requires a fixed price and a fixed proportion of the farm area to be retired. This problem is the same as Policy 2 except that the land retirement constraint (14g) is replaced by:

$$r^h = \tau a_0^h \qquad \forall h$$

Policy 4 requires that producers self-select from a menu of contracts which are give as a transfer payment per hectare b^h and as a proportion of the area retired α^h is the same as Policy 1 except for the addition of the incentive compatibility (IC) constraint

$$\pi^{hh} + b^h \alpha^h a_0^h \geq \pi^{hk} + b^k \alpha^k a_0^h \qquad h,k \in H; \;\; h \neq k.$$

All variable input and output vectors for firms are modified to give x^{hk} and y^{hk}, that is the input and output level when the firm selects 'wrong contracts'. Note that this leads to $(H^2 - H)$ additional constraints for the IC constraint and the profit constraints. The complete nonlinear programming problem is given below:

$$\underset{\alpha^h, b^h}{Maximize} \sum_h \{\pi^{hh} - \lambda b^h \alpha^h a_0^h\} \tag{15a}$$

subject to

$$\vec{D}_o^*(x^{hk}, y^{hk}; g_y) \geq \theta^h \qquad h,k \in H \tag{15b}$$

$$\Delta_y \vec{D}_o^*(x^{hk}, y^{hk}; g_y) \leq 0 \qquad h,k \in H \tag{15c}$$

$$\Delta_x \vec{D}_o^*(x^{hk}, y^{hk}; g_y) \geq 0 \qquad h,k \in H \tag{15d}$$

$$\pi^{hk} = py^{hk} - wx^{hk} \tag{15e}$$

$$r^{hk} = \alpha^k a_0^h \tag{15f}$$

$$\sum_h r^{hh} = \tau \sum_h (a_0^h) \tag{15g}$$

$$a^h \leq a_0^h \tag{15h}$$

$$(\pi_0^h - \pi^{hh}) - b^h \alpha^h a_0^h \geq 0 \tag{15i}$$

$$\pi^{hh} + b^h \alpha^h a_0^h \geq \pi^{hk} + b^k \alpha^k a_0^h \quad h,k \in H; \;\; h \neq k. \tag{15j}$$

4. Data

The data were derived from farm accounts and physical records for a sample of farms in the Great Southern region of Western Australia for 1999. Descriptive statistics for the 61 farms for the 1999 crop year are given in Table A1 in the Appendix. Outputs are given as two aggregate revenue measures: one for crop output and the other for livestock output. Defining outputs as revenues assumes that prices are constant across farms. This is a reasonable assumption for crops which are largely sold to a single cooperative (CBH). Similarly, livestock output is dominated by wool and lamb for the export market and tends to pass through a small number of regional markets. The inputs machinery, services and crop input are given as total costs under these headings. Land is given as hectares, labour as full-time equivalent weeks and stock head as the equivalent of the number of breeding ewes on the basis of forage requirements. Further definitions and units are given in Table A2.

5. Results

5.1 Estimation

The estimation of the distance function was carried out using LP algorithm (GAMS Corporation, 1996). Table A3 presents the parameter estimates of the output distance function. Parameters are estimated using the curvature restriction that the distance function is concave in output. Technical, allocative and profit efficiency measures are given in Table A4. Notably firms appear to be relatively technically efficient, but have a low degree of allocative efficiency.

Table 1 about here

5.2 Policy Comparison

The welfare functions and transfer payment per hectares values are compared for the different policies in Table 1. In the case of Policy 1 (first-best) and Policy 4 (asymmetric information) the transfer payments are given as a range indicating how they vary amongst those farms participating in the scheme. A number of conclusions can be derived from the results. First fixed area schemes Policy 3 are clearly inferior to other policies. This, undifferentiated contract is administratively easy but due to the higher transfer payment will lead to some farmers being overcompensated. Policy 2 (fixed price) performs well and is only slightly inferior to the first-best and asymmetric information policy. The first-best policy with allocative inefficiency (Policy 1b) stands out as giving some unusual results: the welfare value is reduced because firms respond to the policy on the basis of the wrong prices, as the transfer payments are based on a comparison with actual profit rather than maximal profit these are reduced, finally, with the wrong prices area restrictions can actually increase profit by fortuitously increasing a firms allocative efficiency.

6. Conclusion

This paper proposes a non-parametric approach to policy design applied to a land retirement scheme. The analysis makes use of some recent results by Chambers and Fare (2004) on the decomposition of profit efficiency into allocative and technical efficiency. It highlights the issue in mechanism design of determining what is meant by firm type. Here it is defined as technical and allocative efficiency, plus the endowment of fixed factors.

The results indicate that a fixed price scheme is relatively efficient compared with a hypothetical first-best solution. Forcing all farmers to retire a fixed proportion of their area significantly reduces the efficiency of a land retirement policy. A separating solution based on mechanism design gives a small but significant increase in welfare.

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Table 1 Comparison of Policy Options on Contract Design

	Policy(1a) Allocative efficiency		**Policy(1b) Allocative inefficiency**		**Policy(2) Fixed-price**		**Policy(3) Fixed-price and Area**		**Policy(4) Asymmetric Information**	
% of land retired	Welfare Millions Dollars	Transfer Payment (Range) $ per ha	Welfare Millions Dollars	Transfer Payment (Range $ per ha	Welfare Millions Dollars	Transfer Payment $ per ha	Welfare Millions Dollars	Transfer Payment $ per ha	Welfare Millions Dollars	Transfer Payment (Range) $ per ha
5	94.0	12.00-16.78	28.6	7.058-26.130	93.0	16.78	90.5	24.87	93.8	6.01-10.23
10	91.5	21.25-36.49	28.6	6.558-85.045	89.5	36.49	86.7	44.83	89.6	21.25- 71.43
15	88.9	21.25-39.01	28.4	6.090 -26.13(	86.9	39.01	84.0	48.10	88.3	21.25- 345.09
20	86.1	21.25-39.33	28.6	3.829-85.049	84.5	39.33	80.3	67.27	85.8	21.25- 816.34
25	83.4	21.25-39.62	28.7	5.429-93.718	81.9	39.62	76.3	92.91	83.3	21.25- 251.08

Appendix

Table A1 Variable Descriptions

Variable	Description	Unit
Crop revenue	Crop revenue in calendar year	$
Livestock revenue	Revenue from wool, lamb and cattle sales	$
land	Cleared land area	ha
labour	Family and hired labour	weeks
machinery	Total value of machinery	$
Livestock	Stock numbers adjusted to ewe equivalents	Head ewes
crop inputs	Fertiliser, seed and sprays	$
services	Includes overheads postage, phone, subscriptions, accounting and consultancy costs	$
rain	Farm rain during cropping season 1999	mm

Table A2 Descriptive Statistics for Farm Data 1999 (N=61)

Subscript		Units	Average	SD	max	min
1	crop revenue	$	437002	312698	1573255	7373
2	livestock revenue	$	42252	47291	265015	0
1	Land	Ha	2095	1245	7644	520
2	Machinery	$	444597	421879	2625000	34250
3	livestock	hd (ewes)	2449	2184	15655	0
4	labour	weeks	96	43	283	48
5	crop inputs	$	155597	115166	583147	17006
6	rain	mm	442	90	682	279
7	service	$	128887	70687	431247	42388

Table A3 - Parameter Estimates

Parameter	
α_0	-0.078
α_1	0.002
α_2	0.287
α_3	0.004
α_4	0.757
α_5	0.063
α_6	0.012
b_1	-0.219
b_2	-0.781
α_{11}	-1.000E-6
α_{12}	-0.001
α_{13}	-2.846E-6
α_{14}	-1.672E-8
α_{15}	1.394
α_{16}	2.572E-6
α_{21}	-0.001
α_{22}	-1.814E-5
α_{23}	-6.506E-4
α_{24}	2.1997E-4
α_{25}	0.002
α_{26}	2.9947E-4
α_{31}	-2.846E-6
α_{32}	-6.506E-4
α_{33}	-2.291E-5
α_{34}	-0.004
α_{35}	-0.01
α_{36}	-2.543E-4
α_{41}	-1.672E-8
α_{42}	2.199
α_{43}	-0.004
α_{44}	-0.003
α_{45}	-0.030
α_{46}	-0.004
α_{51}	1.3942E-4
α_{52}	0.002
α_{53}	-0.001
α_{54}	-0.030
α_{55}	-0.019
α_{56}	0.073
α_{61}	2.5725E-6
α_{62}	2.9947E-4
α_{63}	-2.543E-4
α_{64}	-0.004
α_{65}	0.073
α_{66}	-4.479E-5
β_{11}	0
β_{12}	0
β_{21}	0
β_{22}	0
γ_{12}	-9.398E-5
γ_{11}	0.002
γ_{22}	-0.006
γ_{21}	-0.023
γ_{31}	0.001
γ_{32}	0.004
γ_{41}	0.008
γ_{42}	0.020
γ_{51}	-0.001
γ_{52}	0.009
γ_{61}	-0.002
γ_{62}	-0.013

Outputs: Crop =1, livestock =2; Inputs: Land = 1, Machinery = 2, Livestock = 3, Labour = 4, Crop inputs 5, Rain = 6, Services = 6

Table A4 Technical and Allocative Efficiency

Firm No	π_0	$\pi(p^s, w^s)$	$\pi(p, w)$	$\vec{D}_o(x^h, y^h; 1)$	NE	AE
1	2.556	5.827	15.689	0.200	6.5665	4.931
2	0.814	2.149	11.914	0.205	5.55	4.8825
3	4.534	8.182	19.011	0.110	7.2385	5.4145
4	2.260	5.211	13.3	0.105	5.52	4.0445
5	2.399	4.088	15.63	0	6.6155	5.771
6	1.941	5.247	14.72	0	6.3895	4.7365
7	0.469	3.393	12.714	0.254	6.1225	4.6605
8	5.118	11.189	21.045	0	7.9635	4.928
9	0.687	2.406	10.95	0	5.1315	4.272
10	5.800	13.835	16.586	0	5.393	1.3755
11	1.120	2.946	12.928	0.108	5.904	4.991
12	1.013	3.029	10.333	0.037	4.66	3.652
13	0.469	2.162	14.132	0.030	6.8315	5.985
14	2.077	4.523	15.798	0.164	6.8605	5.6375
15	0.820	3.877	14.277	0.756	6.7285	5.2
16	1.928	5.575	14.485	0.362	6.2785	4.455
17	3.185	6.632	13.102	0.213	4.9585	3.235
18	0.961	3.017	11.02	0.179	5.0295	4.0015
19	1.370	3.272	12.918	0.144	5.774	4.823
20	0.362	3.945	9.759	0.209	4.6985	2.907
21	5.256	8.509	15.457	0	5.1005	3.474
22	9.080	17.876	24.69	0	7.805	3.407
23	5.142	9.587	20.407	0.017	7.6325	5.41
24	1.511	3.106	10.332	0	4.4105	3.613
25	0.371	1.95	9.684	0.084	4.6565	3.867
26	0.748	6.414	18.824	0.280	9.038	6.205
27	0.609	2.173	12.217	0.157	5.804	5.022
28	1.237	3.728	12.562	0.118	5.6625	4.417
29	0.975	3.58	9.501	0.329	4.263	2.9605
30	0.612	3.651	11.201	0.128	5.2945	3.775
31	1.645	3.091	13.332	0.034	5.8435	5.1205
32	5.998	11.798	22.305	0.121	8.1535	5.2535
33	1.995	5.181	12.632	0.121	5.3185	3.7255
34	0.673	4.014	15.849	0.289	7.588	5.9175
35	0.892	3.693	11.526	0.193	5.317	3.9165
36	1.771	3.816	10.578	0.654	4.4035	3.381
37	2.442	6.098	12.869	0.192	5.2135	3.3855
38	2.060	5.672	13.128	0.247	5.534	3.728
39	3.917	8.877	24.291	0.098	10.187	7.707
40	1.944	4.642	12.641	0.219	5.3485	3.9995
41	1.836	7.427	19.229	0.317	8.6965	5.901
42	1.603	5.325	19.407	0.385	8.902	7.041
43	1.616	3.493	12.852	0.036	5.618	4.6795
44	7.613	11.617	21.107	0	6.747	4.745
45	3.257	8.199	19.652	0.886	8.1975	5.7265
46	1.724	5.736	14.15	0.357	6.213	4.207
47	1.182	5	15.302	0.696	7.06	5.151
48	0.690	2.498	12.963	0.550	6.1365	5.2325
49	5.026	9.74	20.621	0	7.7975	5.4405
50	2.287	5.7	17.196	0	7.4545	5.748
51	2.874	6.352	17.963	0.152	7.5445	5.8055
52	3.705	5.918	14.377	0.210	5.336	4.2295
53	2.765	5.072	14.831	0.133	6.033	4.8795
54	5.369	9.521	23.228	0	8.9295	6.8535
55	2.669	6.473	17.236	0.175	7.2835	5.3815
56	1.431	3.558	14.128	0.184	6.3485	5.285
57	2.348	5.235	17.999	0.084	7.8255	6.382
58	2.589	9.948	26.317	0.430	11.864	8.1845
59	-0.503	1.548	9.529	0.369	5.016	3.9905
60	3.111	8.908	27.238	0.278	12.0635	9.165
61	1.538	3.287	15.932	0.442	7.197	6.3225