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Production costs and input substitution in Zimbabwe's smallholder agriculture

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Abstract

In this study, we estimate production costs and elasticities of factor substitution for Zimbabwean smallholders, using a dual (cost function) approach with detailed data on prices paid and received by each of 65 farms across six survey sites over two years. We find that 95% of observed farm choices are consistent with optimal input use, and that there is moderate substitutability between labor, biochemical inputs and capital. These results indicate that farmers can substitute between factors as relative prices change, particularly to increase labor use as the rural population grows. By stratifying our sample, we investigate the degree to which production costs differ among the socioeconomic groups, tsting for higher costs among female-headed households (who might be subject to gender discrimination), resource-poor farmers without their own draft animals (who might have less timely operations), and isolated farms far from paved roads (who might have less access to markets and information). We find significant support only for the paved-roads effect, indicating the importance of rural infrastructure in determining production costs. © 1997 Elsevier Science B.V.

1. Introduction

Economic analyses of African agriculture are often limited by a lack of basic data on technical parameters. In this study, we use the results of a detailed farm survey to estimate per-hectare cost functions for smallholders in Zimbabwe. The cost functions provide a complete set of aggregate substitution parameters for use in a wide range of policy analyses, and permit us to test key hypotheses about the substitution of labor capital and purchased biochemical inputs, and the impact of socioeconomic factors on production cost.

Farmers' substitution of labor for other inputs is important particularly because Zimbabwe is in an early stage of demographic transition and structural transformation, and the rural labor force is expected to continue rising for many years. As the number of workers per hectare rises, we wish to know whether labor can successfully substitute for other inputs, and also whether increased use of *all* inputs can raise output per hectare. We find, with the current technology, that all aggregate inputs—labor, purchased inputs, and draft capital implements—are substitutes for one another, and that per-hectare yields rise roughly in proportion to simultaneous increases in all inputs. These data provide strong evidence that farmers in the African environment can and do substitute between labor and other inputs, and that production increases on a fixed land base are feasible with the existing technology.

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Regarding the impact of socioeconomic variables, we find that production costs are slightly higher for female-headed households and households which do not own draft animals, but this result is not statistically significant at the 90% confidence level. In contrast, there is strong evidence that costs are higher for households located further from paved roads. This rural-infrastructure effect compounds the higher transaction costs paid by the more remote farmers, which are already included in farm gate prices. The link between infrastructure and production efficiency could result from the more remote farmers' limited access to information, about either market conditions or other farmers' practices.

2. Review of the data

This study utilizes farm level data collected during the 1988–1989 and 1990–1991 crop years by the Farm Management Research Section of the Ministry of Lands, Agriculture and Rural Resettlement (Farm Management Research Section, Ministry of Lands, Agriculture and Rural Resettlement, 1989, 1991). We use these data to estimate a multi-input multi-output cost function for a cross-section of 65 smallholder farmers drawn from six survey sites, in the Kandeya, Mutoko, Chirumanzu, Nyajena, Chiweshe, and Chirau communal areas.

In the survey sites, the amount of crop land available per household member ranges from 0.15 ha/person in Mutoko to 0.33 ha/person in Chirumanzu. Households have an average of two members residing off the farm, providing some monthly remittance from off-farm employment. Additional descriptive household statistics are presented in Table 1.

Table 2
Percentage of arable land cultivated by crop in 1988–1989

Site/Variable	(1)	(2)	(3)	(4)	(5)	(6)	Mean
Maize	56.5	59.1	58.7	50.2	63.0	76.0	61.3
Groundnuts	2.5	12.0	14.6	10.7	11.5	9.1	10.1
Millet	0.9	20.6	25.0	23.3	5.5	2.6	13.0
Sorghum	0.2	1.4	0.5	7.1	0.0	0.0	1.5

Source: Farm Management Research Section, Ministry of Lands, Agriculture and Rural Resettlement, 1989.
(1) Kandeya, (2) Mutoko, (3) Chirumanzu, (4) Nyajena, (5) Chiweshe, (6) Chirau.

In Zimbabwe as a whole, maize is the major crop, occupying more than 50% of all land cropped and providing more than 65% of gross farm income (Central Statistical Office, 1989). Table 2 indicates the percentage of arable land in each survey site that is allocated to maize and the other major crops, while Table 3 presents the average per hectare value of inputs applied on the farms. The percentage of total variable costs attributed to maize production is accordingly high, ranging from 50% in Mutoko to over 91% in Chirau. In percentage terms, the value of inputs applied to groundnuts is second but costs attributable to small grains are not significantly different from those of groundnuts. The amount of family labor applied on groundnuts is significantly higher than the amount of labor applied to small grains, but the majority of family labor is applied to maize.

The bulk of the production costs are attributable to labor inputs. Aggregate biochemical inputs, con-

Table 1
Household descriptive statistics in 1988–1989

Site/Variable	(1)	(2)	(3)	(4)	(5)	(6)	Mean
No. of members	11.60	9.80	7.10	11.90	8.00	9.30	9.60
Arable area (ha)	4.14	1.51	2.38	3.43	2.48	2.43	2.73
% Female-headed	0.00	11.00	16.00	25.00	16.00	25.00	15.60
Distance to tarred road (km)	19.90	2.60	15.10	44.20	8.10	11.50	16.90
Number of cattle (head)	10.37	5.36	5.85	7.68	6.33	8.27	7.31
% Hiring draft services	13.30	45.10	34.20	12.10	25.00	5.90	22.60

Source: Farm Management Research Section, Ministry of Lands, Agriculture and Rural Resettlement, 1989.
(1) Kandeya, (2) Mutoko, (3) Chirumanzu, (4) Nyajena, (5) Chiweshe, (6) Chirau.

Table 3
Whole farm per hectare input use for 1988–1989 (Z$/ha)

Site/Variable	(1)	(2)	(3)	(4)	(5)	(6)	Mean
Seeds	22.84	25.03	19.40	14.78	25.51	21.81	21.56
Chemicals	34.79	0.00	0.30	0.00	1.18	0.97	6.21
Fertilizers	73.05	20.24	16.66	3.22	154.97	35.81	50.66
Hired labor	4.88	4.23	23.30	6.24	9.23	1.79	8.28
Own labor	100.30	218.75	238.72	80.02	182.73	68.99	148.25
Draft	80.05	52.08	83.64	56.84	97.18	25.77	65.93
Transport	28.29	8.30	9.52	1.78	45.24	36.12	21.54
Total	344.20	328.63	391.54	162.88	516.04	191.26	322.43

Source: Farm Management Research Section, Ministry of Lands, Agriculture and Rural Resettlement, 1989.
(1) Kandeya, (2) Mutoko, (3) Chirumanzu, (4) Nyajena, (5) Chiweshe, (6) Chirau.

sisting of seed, herbicides, pesticides, and fertilizers has the second largest cost share and much of this cost share is attributable to fertilizers. The remaining costs are associated with animal draft power and transportation of crops and inputs.

To estimate the cost function, we aggregate output into two categories (maize and other crops) and aggregate production inputs into three categories (labor, biochemical inputs, and physical capital). Cost shares and price levels are calculated for each farm in each year, and the aggregate cost function is then fitted to the entire dataset.

Labor use is the total of all cropping activities, including time spent in plowing and on-farm transport. Male and female labor is counted equally, but children's labor is discounted to half of an adult hour. The household's implicit wage rate is derived by taking total farm income (sales plus retentions valued at their opportunity cost), subtracting total costs (purchased inputs and the imputed annual cost of durable assets), and dividing by total hours worked. All product and input prices are measured at the farm gate, taking account of all reported farm-to-market transport costs. The resulting implicit wage thus includes returns to all household attributes not otherwise accounted for, including unobserved human capital, land quality, and other factors.

Biochemical inputs are a composite of seed, fertilizer, and pesticides. Prices include all transaction costs, including both farm-to-market transportation charges and other marketing activities embodied in price. Prices would be higher, for example, for farmers that buy small quantities from a local trader than for those that buy large lots directly from the manufacturer.

The third category of inputs, capital, is calculated from the imputed annual cost per unit of durable tools and equipment. The annual price of the equipment is calculated by taking the farmer estimated current value of the item, subtracting its salvage value and multiplying the difference by the capital recovery factor (CRF). The CRF assumes a 10% real rate of interest and a 10-year life for manual implements, and a 20-year life for animal traction implements.

3. Theory and estimation

The theoretical model underlying this analysis is grounded in the duality principles developed by Samuelson, Shephard, Uzawa and Diewart, representing the implications of optimization in a competitive market. To fit our limited data, we use a single-period, non-stochastic formulation. The elasticities of substitution are derived from the resulting cost-minimizing factor demand equations.

The minimum cost of producing an output is defined as:

$$C(w,Q) = \min_{x \geq 0} \{ w(x) \cdot x | x \in V(Q) \} \quad (1)$$

where w is a vector of factor prices, x is a vector of inputs and $V(Q)$ is the input allocation set defined as convex, closed, bounded and non-empty for all $Q > 0$. Formally, $V(Q) = \{x \in \Re^N: (-x, Q, 0) \in Z\}$, with $V(Q) = \varnothing$ if it is infeasible for the household to produce. Z is the aggregate supply vector of k producers.

Assuming that farmers cannot influence their input or output prices, the cost minimizing input demands can be found by application of Shephard's lemma:

$$\frac{\partial C(w,Q)}{\partial w_r} = C_r = x_r^*(w,Q)\ \forall\, r = 1, \ldots, R \qquad (2)$$

One objective of this study is to estimate the elasticities of substitution between factors. Morishima elasticities provide a scalar measure of how the relative intensity of input use responds to a change in an input price; this is a measure of the asymmetric substitution possibilities that closely approaches Hicksian substitutability. [2] The Morishima measure is the difference between the constant output cross-price elasticity of demand and the own-price elasticity of demand of the denominating factor price:

$$\sigma_{rs}^{\mathrm{M}} = \partial \ln\left[x_r^*(w,Q)/x_s^*(w,Q)\right]/\partial \ln w_s \equiv \epsilon_{rs} - \epsilon_{ss} \qquad (3)$$

The effect of varying the s-th price is, thus, clearly divided into two parts: the proportional effect on x_r^* of varying w_s (ϵ_{rs}), and the proportional effect on x_s^* of varying w_s (ϵ_{ss}). Own-price effects cancel out and so the diagonal elements of the elasticity matrix are zero.

A translog cost function was estimated pertaining to three inputs (labor, purchased biochemical inputs, and capital) and two outputs (maize and all other crops) plus binary variables for location and year. Biochemical inputs include fertilizers, herbicides, pesticides and seed while the capital input consists of animal and manual traction implements. The 'all other crops' variable consists primarily of sorghum, millet, and groundnuts. The model consists of five equations: the translog cost function, two of the three factor cost shares, and two revenue shares as presented in Eq. (4).

$$\begin{aligned}
\ln\mathrm{TC} = {} & \alpha_0 + \sum_{i=1}^{2} \alpha_i \ln Q_i \\
& + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} \delta_{ij} \ln Q_i \ln Q_j + \sum_{r=1}^{3} \beta_r \ln W_r \\
& + \frac{1}{2}\sum_{r=1}^{3}\sum_{s=1}^{3} \gamma_{rs} \ln W_r \ln W_s \\
& + \sum_{i=1}^{2}\sum_{r=1}^{3} \rho_{ir} \ln Q_i \ln W_r + \sum_{d=1}^{5} \zeta_d L_d + \theta T \\
S_r = {} & \beta_r + \sum_{s=1}^{3} \gamma_{rs} \ln W_s \\
& + \sum_{i=1}^{2} \rho_{ir} \ln Q_i \text{ for } r = 1,2,3 \\
R_i = {} & \alpha_i + \sum_{j=1}^{2} \delta_{ij} \ln Q_{ij} \\
& + \sum_{r=1}^{3} \rho_{ir} \ln W_r \text{ for } i = 1,2
\end{aligned} \qquad (4)$$

The parameters are calculated by the iterated Seemingly Unrelated Regressions method yielding generalized least squares estimates. All variables are defined as follows:

TC	Total cost (Z\$/ha)
Q_1	Quantity of maize produced (kg/ha)
Q_2	Quantity of other crops produced (kg/ha)
W_1	Returns to family and hired labor (Z\$/h)
W_2	Price of biochemical inputs (Z\$/kg)
W_3	Annualized price of durable equipment (Z\$/unit)
L_1	Binary variable for Kandeya survey site
L_2	Binary variable for Mutoko survey site
L_3	Binary variable for Chirumanzu survey site
L_4	Binary variable for Nyajena survey site
L_5	Binary variable for Chiweshe survey site
T	Binary variable for 1990 survey year
S_r	r-th input cost share cost for $r = 1, 2, 3$
R_i	i-th product revenue divided by total cost, for $i = 1, 2$

Linear homogeneity of factor prices and symmetry restrictions were imposed a priori. Homogeneity

[2] Allen partial elasticities of substitution, as derived by Uzawa (1962), are more commonly presented. However, the Allen measure does not indicate curvature or ease of substitution. The Allen elasticity is a one-input-one-price elasticity of substitution obtained from a derived demand function. It does not relate the optimal input ratio to the input price ratio and, thus, cannot provide information on the relative input responsiveness to changes in relative input prices. See Blackorby and Russell (1989) for a complete discussion on the shortcomings and merits of the Allen and Morishima elasticity measures.

Table 4
Parameter estimates for the translog cost function with two outputs and three inputs

	Coefficient	T-ratio		Coefficient	T-ratio
α_0	−0.3830	−1.0998	γ_{33}	0.0309	5.3837[a]
α_1	0.2480	4.4784[a]	ρ_{11}	−0.0439	−3.2632[a]
α_2	0.7323	12.9470[a]	ρ_{12}	0.0754	5.6189[a]
δ_{11}	0.1311	8.3985[a]	ρ_{13}	−0.0315	−5.1914[a]
δ_{12}	−0.0989	−6.5829[a]	ρ_{21}	0.0709	4.7638[a]
δ_{22}	0.0647	3.5844[a]	ρ_{22}	−0.0692	−4.8690[a]
β_1	0.5477	8.7502[a]	ρ_{23}	−0.0017	−0.2561
β_2	0.2292	3.2961[a]	ζ_1	1.0249	3.4436[a]
β_3	0.2229	6.1799[a]	ζ_2	0.0842	0.2286
γ_{11}	0.0422	1.7997	ζ_3	1.2463	3.8106[a]
γ_{12}	−0.0299	−1.3762	ζ_4	0.9205	2.9851[a]
γ_{13}	−0.0123	−1.5938	ζ_5	0.4309	1.4543
γ_{22}	0.0484	2.1409[a]	θ	0.3985	4.4238[a]
γ_{23}	−0.0184	−2.2192[a]			

Cost function $R^2 = 0.8388$, $n = 65$.
[a]Significantly different from zero with a P-value less than 0.025.

of degree one in factor prices, given Q, implies the following linear restrictions:

$$\sum_r \gamma_{rs} = 0 \ \forall \ s$$
$$\sum_i \rho_{ir} = 0 \ \forall \ r \tag{6}$$

while the symmetry conditions of the cross-price effects implies $\gamma_{rs} = \gamma_{sr}$ $\forall$ r, s, and the cross-output effects $\delta_{ij} = \delta_{ji}$ $\forall$ i, j. The parameter estimates and asymptotic t-ratios appear in Table 4.

Many of the parameter estimates (20 out of 27) are significantly different from zero. The translog cost function is often criticized because no parametric restriction ensures global concavity with respect to factor prices or even concavity over the positive orthant (Chambers, 1988). The symmetric Hessian, derived by differentiating Eq. (2) with respect to factor prices, fulfills necessary and sufficient conditions for quasi-concavity if it is negative semi-definite. As Antle and Capalbo (1988) describe, the relevant elements of the Hessian matrix associated with a translog function are $H_{rr} = \gamma_{rr} + S_r^2 - S_r$ and $H_{rs} = \gamma_{rs} + S_r S_s$ for $r \neq s$, where H_{rs} denotes the intersection of the r-th row and the s-th column of the Hessian matrix. The resulting Hessians derived from parameters estimated in the cost function and from farmer's observed cost shares are quasi-concave (negative semi-definite) for 95% of the sample (62 of 65), indicating that almost all farmers' observed input choices are consistent with cost minimization.

4. Elasticities of factor substitution

Applying Shephard's lemma (Eq. (2)) to the translog cost function (Eq. (4)), the Morishima elasticities of substitution may be written, after some manipulation:

$$\sigma_{rs}^{\mathrm{M}}(w,Q) = \frac{w_s C_{rs}(w,Q)}{C_r} - \frac{w_s C_{ss}(w,Q)}{C_s}$$
$$= (\gamma_{rs} + S_r S_s)/S_r - (\gamma_{ss} + S_s^2 - S_s)/S_s$$

where the subscripts on the factor prices and shares denote the elements. The Morishima elasticities and the constant output elasticities of demand are presented in Table 5.

Table 5
Cost shares, elasticities of substitution and demand

	Labor	Biochemical inputs	Capital
Cost shares (S_m)	0.6150	0.3246	0.0603
Morishima elasticities of substitution (σ_{mn}^M)			
Labor	0	0.8022	0.4685
		(15.9068)	(19.2476)
Biochemical inputs	0.8391	0	0.4317
	(15.8805)	(15.3483)	
Capital	0.7263	0.5444	0
	(17.6145)	(11.8515)	0
Constant output price elasticities of demand (ϵ_{mn})			
Labor	−0.3162	0.2760	0.0402
	(−14.8643)	(13.6286)	(12.1606)
Biochemical inputs	0.5229	−0.5262	0.0034
	(13.6284)	(−14.8696)	(3.1978)
Capital	0.4101	0.0182	−0.4283
	(12.1505)	(3.1977)	(−20.2272)

The t-ratio is presented in parentheses. Standard errors for the elasticities are generated by bootstrapping the sample set and generating 600 new samples by replacement. A Taylor series expansion generated a similar pattern of results with slightly larger standard errors. The t-ratio generated by the Taylor series expansion for the biochemical input–capital elasticity (and consequently the capital–biochemical elasticity) was lower and not significantly different from zero. Both methods only provide asymptotic approximations to the true standard errors.

The Morishima elasticities indicate a range of substitutability between labor, purchased inputs and capital consistent with a priori expectations and the results of similar studies in elsewhere such as that of Ali and Parikh (1992) for Pakistan. [3] Any comparison must take into account the substantial differences in agroecological conditions (e.g., the absence of irrigation in the Zimbabwean sample, and its limited importance in Pakistan) as well as differing cost shares (particularly the greater share of labor in Zimbabwe than in Pakistan). Despite the differences, it is notable that the cross-price elasticities of demand for labor and biochemical inputs are virtually identical while our elasticity between biochemical and labor inputs is slightly lower.

The greatest degree of substitutability arises in response to price changes for labor (column 1) and biochemical inputs (column 2) with less response to changing prices for capital items (column 3). The largest single substitution possibility is between labor and biochemical inputs, representing the main alternative methods by which farmers can raise per-hectare yields. This result confirms that if relative labor costs fall (or relative biochemical input costs rise), we can expect to see greater intensity of labor use in such yield increasing activities as weeding, pest management, or soil and water conservation activities. The data confirm that farmers do have substantial substitution possibilities at their disposal, even with the current technology.

In the short run, labor is likely to become increasingly abundant relative to land, as Zimbabwe is still in an early stage of structural transformation: although nonfarm employment could well grow at a faster rate than the total labor force, the absolute size of the nonfarm sector is still so small that the absolute number of new nonfarm jobs is well below the number of new entrants into the labor force. As a result, the farm labor force must continue to grow—against a fixed land base—until the nonfarm sector is big enough to absorb all of the annual workforce growth.

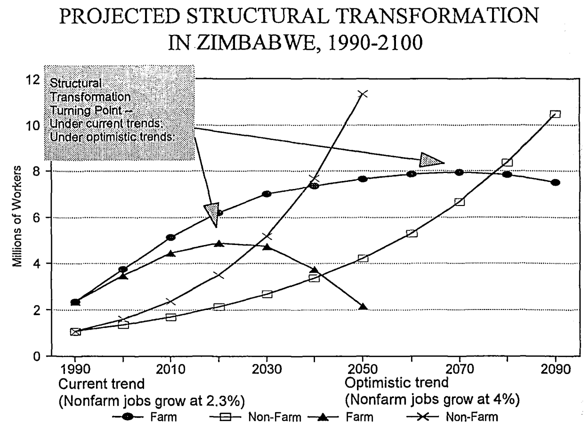

Fig. 1. Structural transformation scenarios.

To quantify the likely increase in the agricultural workforce, we draw on Masters (1994) (p. 14), who uses data from the 1982 census and Zimbabwe's official population projections (Central Statistical Office, 1985, 1986) to estimate future growth in the total labor force. Subtracting alternative scenarios for nonfarm employment growth then yields alternative scenarios for the number of agricultural workers.

Selected results for such projections are presented in Fig. 1. The 'current trends' case is based on actual growth in nonfarm employment (2.3%) during the 1980s; if these trends continue, the agricultural workforce could increase three-fold over the next 75 years. The 'optimistic' case is based on a return to earlier nonfarm employment growth rates (4%); in this scenario, the agricultural workforce might only double, and could begin to decline within 30 years.

In virtually any plausible scenario, the agricultural workforce grows rapidly over the next 15–20 years, raising the availability of labor per hectare. Our results suggest that, at least for marginal changes of the magnitude observed within our sample, more intensive labor use is feasible with current technology. This intensification could occur either in conjunction with or in substitution for other nonland inputs, depending on the trend in the prices of these inputs relative to labor.

If prices of capital and biochemical inputs stays constant relative to labor, intensification could in-

[3] Ali and Parikh present Allen and constant output price elasticities. The Allen elasticities derived from our data are, however, different from the Ali and Parikh results because the cost shares differ. The Allen elasticities may be derived from Table 5 with the following equation: $\sigma_{rs}^{A} = \epsilon_{rs} / S_s$. The comparable terms, ϵ_{rs} $\forall$ r, s, are strikingly similar in our sample as in the Ali and Parikh data for the main substitution possibilities: labor and biochemical inputs.

Table 6
The impact of gender, draft ownership and distance on the cost function

Variable	Type	Coefficient	T-ratio	P-value
Female-headed household	Binary (1 = F.H.H.)	0.1110	1.1386	0.259
Draft ownership	Binary (1 = Own)	−0.1195	1.4624	0.148
Log household distance from nearest road	Continuous	0.0699	1.7407 *	0.086

Significantly different from zero with a P-value less than 10%.

volve increased use of all inputs, and our results imply this is likely to yield roughly proportional increases in output. On the other hand, if the real wage should fall relative to the cost of capital and biochemical inputs, our results suggest labor could substitute for them as well as for land.

The estimated substitution elasticities permit some optimism about the ability of the Zimbabwean smallholder farming system to absorb labor in the coming years, through a process of intensification that is similar to that undertaken in Asia and throughout the world. Such substitution does not imply that the rapid population growth is costless, but it does imply that smallholder agriculture can and will be a key source of employment during the structural transformation process.

5. Impact of socioeconomic variables on productivity

In addition to population growth, observers often point to socioeconomic variables such as gender or location as key determinants of agricultural productivity. The model and data presented in this paper permit us to test three commonly discussed hypotheses in this area: that all other things equal, productivity is lower for female-headed households, households without their own draft power, and households further from main roads.

Female-headed households may have lower physical productivity because they are discriminated against by extension agents, lenders, or others; they may also have higher costs because of unobserved variables such as nutrition, health or other factors. Households without their own draft animals may be less productive because critical operations are performed in a less timely manner. Finally, more distant households may have lower productivity because they are isolated from input and product markets, and so, have less information and higher transaction costs than other households.

These hypotheses are tested by adding variables for female-headed households and draft ownership as intercept shifters to the cost function in Eq. (4), while the log of the distance of the household to the nearest paved road is included as a continuous variable to indicate spatial segregation but it is not interacted with the inputs or outputs. The results of these hypotheses tests are presented in Table 6.

The sign on the female-headed household variable is positive, supporting our hypothesis, but the parameter is not statistically significant from zero at the 10% level. Approximately 15% of the farms in our sample are female-headed, a figure which is identical to the average for all communal areas (Farm Management Research Section, Ministry of Lands, Agriculture and Rural Resettlement, 1989, 1991). Similarly, the sign on the variable for households owning draft animals is negative, but the variable does not shift the intercept significantly when evaluated at the 10% significance level. We urge caution in interpreting the results of both variables because of the small sample size for both categories. [4] We find, however, more significant support for the third hypothesis, as the further a farm is located away from a paved road, the higher its cost of production.

In order to ascertain why households do not all own their own draft animals and to determine whether one source of inefficiency for female-headed households lies in the lack of draft ownership, a univariate binary Logit model was created to determine the marginal impact of important explanatory variables on the probability of draft ownership:

$$P(\text{Draft Ownership}_i = 1) = F(x_i, \beta) \quad (8)$$

where P is the probability of draft ownership, $\boldsymbol{x}_i$ is

[4] The small sample sizes prevented investigation and correction for sample selectivity bias as discussed by Heckman (1979).

Table 7
Logit analysis on the probability of draft ownership

Variable	Coefficient	T-ratio
Distance to tar road	0.0697	1.7837[a]
Years farming	0.0243	0.6313
Large ruminant herd size	0.2566	2.3135[a]
Nonfarm income	0.0013	0.8983
Female-headed household	−1.5898	−1.4800
Average distance to plots	−0.0822	−0.2348
Hectares cultivated	0.4184	1.5064
Constant	−3.1726	−1.8674[a]

Log likelihood function = ± 22.818.
McFadden $R^2 = 0.371$.
Percentage of correct predictions 0.846.
[a]Significantly different from zero with a P-value less than 10%.

a vector of household characteristics, for all households I, and $\boldsymbol{\beta}$ is a vector of unknown parameters. The sex of the household head is included as one of seven explanatory variables. The model results are presented in Table 7.

The sign on the female-headed household variable is negative, but again, not at a significant level. Similarly, farm size and distance to plots do not significantly influence the probability that a given farmer will own draft animals, nor does farming experience and nonfarm income. The major determinant turns out to be the total size of livestock holdings. This result is consistent with the argument that the farmer-to-farmer market for trained adult animals is repressed by restrictions on cattle movement, benefiting farmers who can breed and train their own oxen.

6. Conclusions

This paper uses detailed farm survey data to estimate a cost function and input substitution possibilities for smallholder farmers in Zimbabwe. To our knowledge, cross-sectional estimates of production elasticities have not been updated since the late 1960s (Johnson, 1964; Massell, 1967; Massell and Johnson, 1968) and have not been estimated using a dual approach. We found that labor, biochemical inputs and capital are substitutes and that the degree of substitutability varies greatly between inputs. We also found that our constant output price elasticities of demand for labor and biochemical inputs are very close to those found in a recent study in Asia. Thus, as the farm population rises we expect farmers to intensify their labor use, much as farmers elsewhere have done, and we expect similar substitutions in response to input price changes caused by structural adjustment and policy reforms. In the long run, when increased off-farm employment raises the value of farm labor, we expect inputs and capital to substitute for labor, much as they have done in East Asia and other more industrialized countries.

The cost function approach permits us to test three key socioeconomic hypotheses which often arise in discussions of African agriculture: that productivity is lower among female-headed households, households using rented draft animal services, and more remote households. We find statistically insignificant support for the first two hypotheses; only the last relationship is significant at a 90% confidence level. In addition, we find households are much more likely to have their own draft animals if they own a larger herd, suggesting that opportunities to buy trained adult animals are limited. Our results in this area suggest that differences in the gender of the household head or draft ownership are less important than the household's access to rural infrastructure. The road-proximity effects compound the differences across households in transport costs that are taken into account in farm gate prices, and could reflect the access to information that infrastructure brings.

Taken together, our estimates confirm that the technical parameters of Zimbabwean smallholder farming systems are not qualitatively different from those estimated in other regions. The principal conclusions include that farmers will substitute among inputs in response to changing relative input prices; that farmers will be able to increase production per hectare roughly in proportion to aggregate input use, and that a farmer's relative production costs are more closely linked to their market access than their household's socioeconomic status.

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