NOTES

1. The UNITAD model is a world model which was developed jointly by United Nations Industrial Development Organization (UNIDO) and the United Nations Conference on Trade and Development (UNCTAD). For further details see UNIDO [1982].
2. The literature on shift-share analysis is quite extensive and there are numerous variants of the shift-share technique. For a critical review of the literature of shift-share as well as a comprehensive bibliography on this subject, see Stevens and Moore [1980: 419–37]. Leamer and Stern [1970] also developed independently a similar technique to analyse the relative preformance of export growth in a particular country. For an empirical application of the constant market share analysis, see Banerji [1974: 447–8].
3. Most of the limitations described here also may hold for any econometric relationship except for its stochastic specification containing disturbance terms.
4. The interpretation of negative signs in the table is quite straightforward. For instance, if MVA in agrofood processing in the North were growing at the world average growth rate of total manufacturing (22%), the MVA change would have been $41.5 billion, about 1.87 times the actual value. However, this positive global effect of $41.5 billion (187%) is partly counter-balanced by about $14 billion (−63%) due to the worldwide slower growth of MVA in agrofood processing *vis-à-vis* other industries, and by around $5 billion (−24%) due to the decline in regional effect of the North. This means that the net MVA change was $22 billion.

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The Village Impact of Machine Threshing and Implications for Technology Development in the Semi-Arid Tropics of Peninsular India

*by Thomas S. Walker and K. G. Kshirsagar**

This study evaluates the dynamic consequences of machine threshing in the Semi-Arid Tropics (SAT) of Peninsular India. We rely on a panel of 30 cultivator and 10 landless labour households to monitor, over five cropping years from 1975/76 to 1979/80, the impact of mechanical threshing on the village economy. Machine threshing did not significantly reduce costs, increase cropping intensity, or greatly harm labour. These results are strongly conditioned by the ecological features of the SAT. Their implications for public-sector investment in research on selective threshing mechanisation are drawn.

Recently in this journal, Ghodake, Ryan, and Sarin assessed how improved cropping technologies changed the seasonality of labour demand, and concluded that labour bottlenecks 'could adversely effect the timeliness of operations critical to the success of prospective double-cropping and/or intercropping technology aiming at greatly increased food production' [*1981: 43*]. They expected 'to see increased demand by farmers for selective mechanisation operations such as threshing, where the major bottlenecks would seem to arise' [*44*].

When economists graph the seasonal demand for labour required by prospective technologies, agricultural engineers are usually quick to interpret 'the peaks' as signalling or reinforcing the need for research on selective mechanisation, in this case on the evaluation and design of threshing technologies for the Semi-Arid Tropics (SAT) of India [*Singhal and Thierstein, 1979: 2*].[1] Whether public sector resources should be allocated for research on selective mechanisation depends largely on two criteria – comparative advantage[2] and consequences. In this study, we focus on consequences and measure the impact of machine threshing on cost, employment and cropping intensity in a dryland village economy.

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Addressing dynamic consequences requires time-series data on a cross-section of randomly sampled households. We rely on panel data from 30 cultivator and 10 landless labour households in the ICRISAT Village Level Studies (VLS) [*Binswanger and Ryan, 1980: 123*]. These data are ideally suited for impact analysis because they furnish a before-and-after evaluation along with a with-and-without comparison.[3]

After a brief review of the diffusion of mechanical threshing in India, we describe the introduction and adoption of machine threshers in one village in Maharashtra from 1975/76 to 1979/80 in the next section. Because direct output effects from new threshing technologies are likely to be small, the private profitability of machine threshers and the size of cost reduction are central themes for analysis in the second section. In the third section, we concentrate on the dynamics of price determination within the village economy. In section four, we track the employment histories of workers who threshed sorghum before machines were introduced and who therefore were candidates for labour displacement. The impact of machine threshing on cropping intensity is evaluated with both with-and-without and before-and-after comparisons in the fifth section. The paper concludes with comments on implications for research policy on investment in improved threshing technologies in SAT India.

INTRODUCTION AND DIFFUSION OF MACHINE THRESHERS

The demand for threshers has rapidly expanded in India over the past 20 years. Most of the growth in demand was sparked by the introduction of high-yielding wheat varieties in Punjab, Haryana, and Uttar Pradesh. The early-maturing, high-yielding varieties, together with a rising investment in tubewells, enhanced opportunities for double cropping and stimulated the demand for seasonal threshing labour, which in turn precipitated rapidly rising seasonal wages. Higher wages made threshers a decidedly attractive investment, and the changing economic conditions did not go unnoticed by agricultural engineers and research administrators. In 1966 'in recognition of its great importance, the Indian Council of Agricultural Research (ICAR) offered a prize award for the best prototype design of a low horse-power thresher' [*Roy, 1970: 541*]. The private sector rapidly responded to rising demand by designing simple threshing innovations. Indicative of this response was the finding that the number of mechanical threshers per 100 farmers in four sampled districts of the High-Yielding Varieties Program in the Indian Punjab increased from 2.50 in 1965 to 25.75 in 1970 [*Lockwood, 1972: A120–A121*].

In SAT India

Diffusion of threshers in the SAT of India has not been widespread. For example, by 1972 the density of threshers per 1,000 tonnes of cereal production for the Indian Punjab was 10.5 compared to 0.4 for predominantly rain-fed Maharashtra. Between 1972 and 1977 the number of threshers increased from about 75,000 to approximately 215,000 in Uttar Pradesh, while comparable estimates for Maharashtra show an expansion from about 1,000 to 5,000 [*Directorate of Economics and Statistics, 1980*].

In One SAT Village

Typical of much of SAT India, the traditional modes of threshing cereals and pulses in Kanzara is by bullock power and human labour. Kanzara is located in Akola district in the rain-fed Vertisol, cotton-growing region of Maharashtra. Cotton is generally row intercropped with local sorghum and pigeonpea in the rainy season. Hybrid sorghum is sole cropped at the start of the monsoon. Other pulses are also grown and threshed in the village. Threshing begins after the harvest of mung-bean in September and intensifies in October, December and March after the harvests of hybrid sorghum, local sorghum and wheat respectively.

The first machine thresher was purchased by a villager in 1976. By 1980 five threshers owned by different villagers had been purchased.[4] The threshers run on diesel or electric motors ranging from five to ten horse-power. Farmers do not have sufficient production to make threshers a remunerative investment without hiring out their machines. To increase utilisation, some owners have taken their machine outside the village. In 1980, two machines were threshing in the village, two were operating outside, and one was in need of repair.

The most salient feature about threshing in Kanzara is the rate structure that owners of threshers have adopted to promote increased utilisation of thresher capacity over the season. For sorghum, regardless of the size of output, they retain four per cent of production as a payment for threshing. The first owner in 1976 appears to have skilfully calculated what the market would bear when he introduced the four per cent charge, which has not changed over the past seven years.

Machine threshing rapidly replaced traditional methods. For each cropping year from 1975/76 to 1980/81, the percentage share of hybrid sorghum threshed mechanically was 0, 71, 82, 99, 93, and 99. Similar figures for local sorghum were 0, 59, 82, 66, 52, and 83. By 1979/80, all farmers in the sample had used machines to thresh at least a part of their sorghum production. Moreover, by 1977/78 all wheat produced by farmers in the sample was threshed mechanically.

The determinants of hiring in machines for threshing are presented in a Tobit analysis in Table 1. The dependent variable is the amount of sorghum threshed by machine by household in a cropping year from 1976/77 to 1980/81. Thirty-eight of the 125 sorghum-producing households by cropping year observations did not thresh mechanically; therefore, ordinary least squares would give inconsistent estimates of the parameters of the model [*Tobin, 1958*].

Farmers who owned fewer bullocks, cultivated more land, planted proportionally more hybrid sorghum, and produced more sorghum were significantly more likely to thresh more sorghum mechanically (Table 1). The most important determinant influencing choice of threshing technique was the quantity of production. If, at arithmetic mean levels of all independent

TABLE 1

DETERMINANTS OF HIRING IN MACHINES FOR THRESHING FROM 1976/77 TO 1980/81

Variable	Description of independent variables[a]: Measurement unit	Mean	Expected sign	Tobit estimates: Regression coefficient	t-ratio[c]	Elasticity of E(y)[d]
Bullocks	Number	1.71	-	-138.06	-2.78**	-0.35
Family farm workers	Number	3.58	-	-30.09	-1.24	
Farm size	Operated area in has.	6.50	+	36.40	2.57**	0.35
Hybrid	% hybrid to total sorghum	52.92	+	3.77	2.75**	0.30
Production	Total sorghum production in kgs.	887.15	+	0.78	4.70**	1.03
Production squared		209120.00	-	0.00004	1.27	
Year 1[b]	1976-77=1		-	-340.59	-2.27*	
Year 2[b]	1977-78=1		-	-142.51	-1.08	
Year 3[b]	1978-79=1		-	-140.01	-1.01	
Year 4[b]	1979-80=1		-	-174.79	-1.27	
Log-likelihood function				-753.57		
R^2 between observed and predicted				.88		
Number of observations				135		

(a) The dependent variable is the quantity of sorghum threshed by machine by a sorghum-producing household in a cropping year. Its median value is 710.70 kgs with a standard deviation of 1095.10.
(b) The omitted and reference year is 1980/81.
(c) * and ** indicate statistical significance at the .05 and .01 levels, respectively.
(d) Evaluated for statistically significant coefficients at the arithmetic mean values of the independent variables.

variables, a household experienced a ten per cent rise in sorghum production, machine threshing throughput would proportionally increase by about ten per cent (Table 1).

COST SAVINGS AND PROFITABILITY OF MECHANICAL THRESHING

The widespread use of threshers in Kanzara indicates that it was profitable to thresh with machines. Direct economic superiority may stem from a reduced per unit cost of converting harvested produce into threshed grain, decreased threshing losses, and/or a higher output price reflecting cleaner grain or a lower percentage of brokens. The VLS data suggest that threshing losses and output price do not vary significantly by threshing technique. Therefore, direct benefits attributed to mechanical threshing must largely arise from a lower per unit cost.

Cost Savings

Costs are compared for the three techniques by calculating average input–output coefficients based on the assumption of a fixed-coefficient production function where constant returns to scale and input combinations in fixed proportions are assumed. These coefficients are presented in Table 2 and represent the average number of hours taken to thresh one quintal of sorghum. They are estimated from data on all 367 sorghum plots in the Kanzara sample from 1975/76 to 1979/80. For both hybrids and local varieties and for the three threshing methods, male hired labour is the primary input.[5]

TABLE 2

LABOUR AND BULLOCK INPUTS REQUIRED TO THRESH AND WINNOW ONE QUINTAL OF SORGHUM, BY CULTIVAR AND METHOD, FROM 1975/76 TO 1979/80 IN KANZARA

	Hybrid: Hand	Hybrid: Bullock	Hybrid: Machine[b]	Local: Hand	Local: Bullock	Local: Machine[b]
	-- Hours per threshed quintal[c] --					
Male family	2.74	0.39	0.48	3.98	2.46	0.83
Female family	0.00	0.09	0.12	3.01	0.11	0.07
Male hired	5.48	4.16	1.09	6.15	4.07	1.38
Female hired	3.44	0.25	0.03	2.72	0.02	0.00
Total labour	11.66	4.89	1.72	15.86	6.66	2.28
Bullocks owned[a]	-	1.18	-	-	1.82	-
Bullocks hired[a]	-	0.21	-	-	0.27	-
Total bullock	-	1.39	-	-	2.09	-

(a) Refers to a bullock pair.
(b) Refers to the requirement of the farmer who hires in the machine.
(c) One quintal equals 100 kilograms.

Comparative cost data in Table 3 reveal that the direct cost savings attributable to threshers are not large.[6] Although the relative savings in cost was about 20 per cent, the absolute cost savings was only one to two Rs. per quintal which generates a small, almost negligible, savings in value of production.

Profitability

The profitability of mechanical threshing is directly tied to cereal production in the village. A few calculations highlight this point. Suppose all sorghum and wheat harvested in Kanzara is threshed by machine. Under some reasonable assumptions[7] based on the VLS data and Singhal and Thierstein [*1979: 15*], we estimate an internal rate of return to management and capital of over 100 per cent when one machine of 300 kilograms per hour capacity threshes all available produce. If another thresher of the same capacity is

TABLE 3

COST OF THRESHING HYBRID AND LOCAL SORGHUM, BY METHOD AND CROPPING YEAR

Cropping year	Hybrid			Local		
	Hand	Bullock	Machine	Hand	Bullock	Machine
	---Cost in (%) of value of output---					
1975-76	5.38	4.41	-	6.49	5.88	-
1976-77	4.70	3.78	4.77	7.18	6.34	5.26
1977-78	6.68	5.36	5.08	7.83	6.86	5.34
1978-79	5.50	4.20	4.89	7.26	6.03	5.22
1979-80	5.14	4.04	4.85	6.74	6.07	5.23

brought into the village and the two machines equally divide the harvest, expected profitability on each thresher falls to 30 per cent. The addition of a third and fourth machine of identical vintage lowers the internal rate of return on investment to 13 per cent and 4 per cent respectively.

PRICE DETERMINATION AND THE DIFFUSION OF MACHINE THRESHING

The absence of a significant cost advantage does not make a compelling case for machine threshing. Why did the first machine owner charge four per cent and why has this percentage fee remained intact over the past seven years despite the entry of other machines into the village? With the aid of hindsight, it is possible to draw on micro-economic theory to suggest answers to these questions. We focus on the village and the peak-period demand for and supply of threshing resources. The demand schedule (DD) in Figure 1(a) applies to the short run, perhaps a two-week peak threshing period for hybrid or local sorghum. Demand is inelastic and is given by the size of the crop. The upward sloping supply schedule (SS) indexes the availability of bullock and human threshing labour for changes in their hiring rates (in rupees per quintal threshed). The supply of traditional threshing resources is determined by supply and demand conditions in the bullock and labour markets in the village and in neighbouring villages. It is assumed that a hiring market for bullocks and labour exists.

Before mechanical threshing, output Q_t is threshed with traditional resources at price P_o [Figure 1(a)]. The area PBL under SS and to the left of DD represents payments to bullock owners and labour. Because some farmers employ their own bullocks and family labour for threshing, PBL is distributed to hired labour, owners of hired bullocks, and farmers who use family labour and bullocks for threshing.

One enterprising person in the village buys a thresher and faces the decision of what price to charge. Suppose he picks P_m, the intercept of the

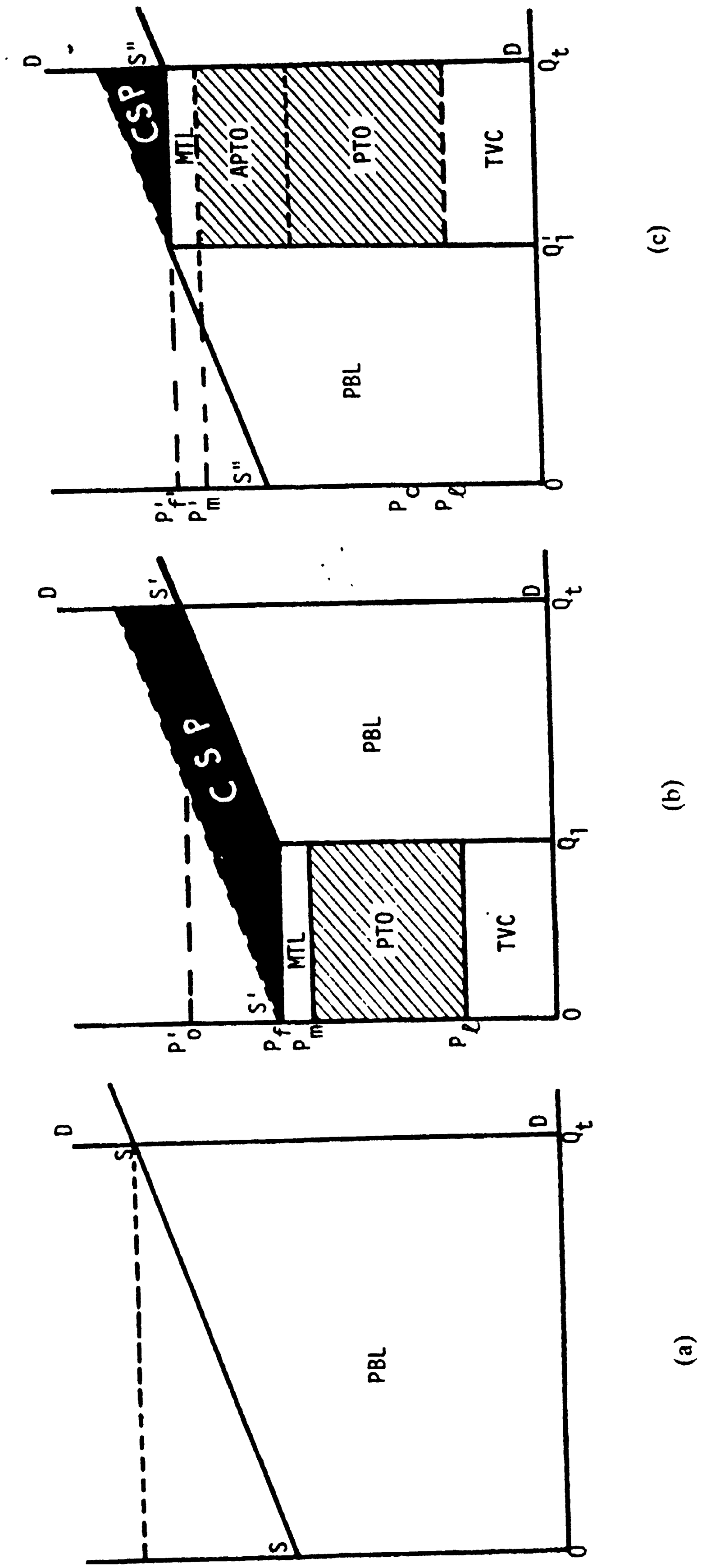


FIGURE 1
SUPPLY AND DEMAND FOR THRESHING RESOURCES AT THE VILLAGE LEVEL

supply schedule SS with the price axis [Figure 1(b)]. We assume that mechanical threshing is a fixed coefficient technology; therefore, a machine can only thresh a fixed quantity (Q_l) of sorghum during the two-week threshing period. We further assume that at full utilisation of capacity it can thresh only a part of the village produce Q_t during the peak demand period. Thus, with machine threshing, SS flattens out along its initial section, shifts to the right and is converted into S′S′. Q_l is threshed by machine at price P_m; (Q_t-Q_l) is threshed by traditional methods at price P'_o. Farmers who hire the machine have to supply their own labour; therefore, the total cost of machine threshing to these farmers is P_f, which includes the payment to machine threshing labour MTL. $P\ell$ represents the variable non-labour cost per quintal threshed for operating the machine. Payments to fuel and other variable inputs are reflected in TVC.

Machine threshing generates cost savings to producers (CSP). The size of CSP represents the magnitude of direct benefits to society due to the introduction of the thresher. PBL shrinks as profits and return on investment (PTO) accrue to the owner of the thresher.

It is in the interest of the thresher owner to charge a price that maximises his return on investment (PTO). If our owner had perfect knowledge of DD and S′S′, he would have established P'_m as his revenue maximising price [Figure 1(c)]. This is the highest price he can charge without losing some of his business to his traditional threshing competitors. At price P'_m he still threshes an amount $(Q_t-Q'_l)$ that equals Q_l. Because he threshes the same quantity as before, PBL, TVC, and MTL do not change. Profits to the owner expand at the expense of CSP, which is greatly reduced. The prices P'_f and P'_o facing farmers who machine hire and those who thresh with traditional techniques are the same. APTO represents an additional quasi-rent to the thresher owner.

Figure 1 illuminates many aspects of the thresher owner's pricing decision. His ceiling price is P'_m Any price above P'_m results in his losing throughput to traditional threshing methods. P_λ, or non-labour variable costs per unit of output threshed, establishes the floor price. Assuming mechanical threshing is profitable, some price in the vicinity of P_c is probably a competitive price that provides an equitable return on investment. P'_m is probably too high a price to charge. In some years, village output may fall considerably short of Q_t. For example, if demand shifted to Q'_l and the owner opted for P'_m his returns would be nil; he would be forced to revise his price downwards.

The owner has to take a longer view when he forms expectations on DD and SS. For the case depicted in Figure 1(c), his chosen price should fall between P'_m and P_c. As the price approaches P'_m direct benefits to society diminish and profits to the owner increase. If the owner chooses a price close to P'_m we should not see a significant difference between the per unit cost of threshing for mechanised and traditional techniques.

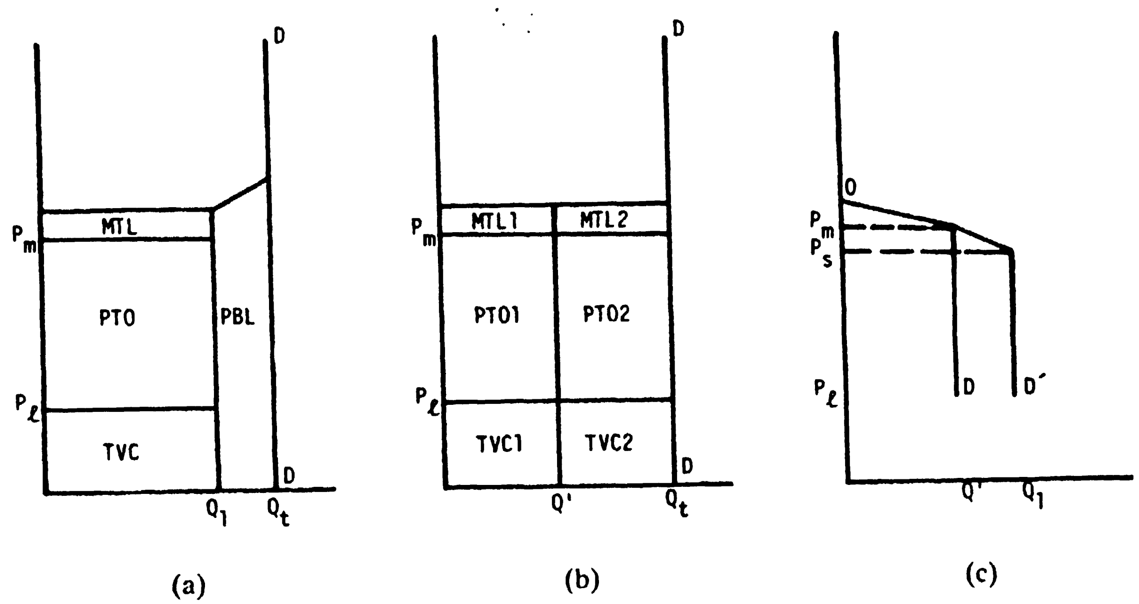
With the increasing entry of mechanical threshers into the village elementary economics would suggest that P_m would fall. Figure 2(a) describes the

case where one thresher operates in the village and charges a price P_m. Q_l is threshed by the single thresher and (Q_t-Q_l) is threshed by traditional methods. Returns (PTO) on investment are large and may entice another resident in the village to purchase a thresher. The addition of a second thresher of identical vintage translates into a reduced market share and decreased revenues to the first owner [Figure 2(b)]. In order to increase revenue and eliminate excess capacity, both owners are motivated to search for unthreshed grain outside the village.

If external demand is weak, the only strategy available to the first owner to recover his market share is to lower his price. As the first owner initially cuts his price on demand schedule OD′ in Figure 2(c), he will regain his market share at the expense of the second owner, who naturally will react by matching the price of the first owner. As both decrease their price the size of PTO will shrink, and both will be worse off than before.

FIGURE 2

ENTRY AND PRICE COMPETITION IN THE VILLAGE THRESHING MARKET



Demand schedule OD′ is drawn on the assumption that the second owner will not react when the first owner changes his prices. The first owner is not so myopic to think that he faces demand schedule OD′. He will realize the interdependency depicted in OD in the firm demand schedules; hence, there is no incentive to lower prices. Initial prices P_m is the best that either owner can do to maximise revenue.

Even with the entry of more threshers into the village, it is not surprising to learn that the price for threshing has not changed in the last seven years in Kanzara. We would expect the constancy of the piece rate payment to hold for other crops such as wheat.

The spatial oligopoly, kinked-demand scenario depicted in Figures 1 and 2 of too many machines chasing too little demand is also supported by other observations. In Gujarat, where wage rates for daily agricultural labour are higher than in Kanzara, owners of low horsepower threshers in the two VLS villages charge five per cent (unpublished VLS data). During the 1980/81 season, the two owners operating threshers in Kanzara were extremely reluctant to have a third machine which was operating outside, return to the village. Singhal also reported that when a private thresher owner heard about an ICRISAT test of a new design near his home village in western Maharastra 'he rushed to the village ... worrying about his business' [*Singhal, 1981: 2*].

EMPLOYMENT

The marked decrease in labour hiring for threshing between 1975/76 and 1978/79 is yet another indication of the speed with which mechanical harvesting technology diffused throughout Kanzara (Table 4). The number of observations where members of VLS landless labour and small farmer households were hired for post-harvest work, mainly sorghum threshing, totaled 40 in 1975/76.[8] By 1978/79 only two observations of labour hired for post-harvest threshing were recorded in the VLS sample.[9]

TABLE 4

WAGES FOR AND FREQUENCY OF POST-HARVEST LABOUR IN KANZARA FROM 1975/76 TO 1978/79

Crop year[a]	Male labour		Female labour	
	Rupees per hour[b]	Number of observations	Rupees per hour[b]	Number of observations
1975-76	.50	30	.25	10
1976-77	.42	33	.26	7
1977-78	.59	17	.45	12
1978-79	.64	2	-	0

(a) Data on time allocation by operation were not collected for 1979/80.
(b) Taken from M. Asokan, 1980. 'Rural Labour Wages and Bullock Rental Rates for Various Agricultural Operations in the SAT of South India, 1975–76 to 1979–80', (unpublished Progress Report 18, Economics Program), Patancheru: ICRISAT.

In order to gauge the impact of mechanical threshers on employment, two questions are asked: (1) what was the level of involuntary unemployment for hired labourers in the VLS sample threshing sorghum during the peak threshing season from 1975/76 to 1977/78, and (2) what was the rate of labour market participation and level of involuntary unemployment in 1978/79 for labourers who threshed sorghum during the previous three seasons?

In other words, did machine threshing lead to increased unemployment for labourers participating in threshing operation and did workers who had previously participated in threshing find alternative employment opportunities in 1978/79?

The answer to the first question appears to be affirmative. The rate of involuntary unemployment rose sharply from 1975/76 to 1977/78 (first two columns, Table 5). Before mechanical threshing in 1975/76, the estimated rate was only seven per cent during the threshing season; by 1977/78 the five workers who were still threshing sorghum 'lost' one day in six to involuntary unemployment. The average levels of involuntary unemployment are statistically different at the five per cent level between 1977/78 and the two earlier cropping years (first column, Table 5).

TABLE 5

INVOLUNTARY UNEMPLOYMENT FOR MALE AGRICULTURAL WAGE LABOURERS DURING PEAK THRESHING FORTNIGHTS FOR HYBRID AND LOCAL SORGHUM FROM 1975/76 TO 1977/78

Crop year	Male labourers hired for sorghum threshing		All male labourers in the village agricultural labour market		
	% Involuntary unemployment[a]	Number of observations in the sample	% Involuntary unemployment[a]	Mean household % involuntary unemployment[b]	No. of households[b]
1975-76	6.5	19	10.7	11.8	26
1976-77	9.6	26	9.3	10.8	25
1977-78	16.9	5	15.8	14.3	23

(a) Total days unable to find work, divided by total days unemployed and employed in the daily agricultural labour market. Peak fortnights refer to October 8–November 4 for hybrids and December 3–31 for local varieties.
(b) Households with males participating in the daily agricultural labour market during these peak fortnights.

Workers who were displaced by mechanical threshers were generally able to find other employment in Kanzara. Twenty-five household members in the sample threshed sorghum in one or more cropping seasons from 1975/76 to 1977/78. Employment histories are available on 20 of these workers who remained in the sample during the peak sorghum threshing periods in 1978/79.[10] These data reveal that five entered the daily agricultural labour market, six obtained monthly regular farm work, four procured off-farm employment, three did not participate in the labour market and worked on their own farms, and two benefited from government employment. For the five daily agricultural wage labourers, the rate of involuntary unemployment was about [illegible]0 per cent during sorghum threshing in October and December. Despite this high percentage, we conclude that the majority of agricultural workers previously engaged in threshing were able to secure alternative employment.

The labour market in Kanzara is buoyant and operates efficiently for males who are the primary source of labour for sorghum threshing [*Binswanger et al., 1979: 16*]. Moreover, sorghum threshing in the diversified agriculture of Kanzara is not such a large source of employment that one would expect a pronounced repercussion on the labour market from the introduction of machines. For instance, we estimate that machines reduced hired male labour use during the two peak fortnights for threshing hybrid and local sorghum by about five per cent at the village level. In 1975/76, sorghum threshing accounted for about 6.0 and 11.1 per cent of male labour hired for crop production in October and December.[11] By 1977/78, these percentages had fallen to 2.6 and 5.1.[12] Therefore, the net reduction in male hired labour demand at the village level was around 3.4 and 6.0 per cent. The wage rate data in Table 4 and the unemployment probabilities in the last three columns in Table 5 further suggest that the decrease in demand was not large enough to be markedly felt in the village. The mean levels of involuntary unemployment for households with male participation in the daily agricultural labour market were not significantly different (at $p<.05$ or even $p<.10$) across the three cropping years.

These results should be interpreted with caution because we expect labour displacement to be much stronger in other SAT production environments, particularly in rainy season fallow areas where postrainy season sorghum is sole cropped and is the dominant crop. Labour displacement would also be more severe if multipurpose machines were designed to thresh both cereals and pulses such as pigeonpea, mung-bean and black-gram which are grown in considerable quantities by many households in Kanzara. Unlike cereals, most pulses are threshed by hand beating which is intensive in its demand for female labour.[13] It is unlikely that women could find alternative employment as readily as men [*Ryan and Ghodake, 1980: 13*]. This prediction applies especially to pigeonpea threshing during February and March before the slack months of April and May. The probability of females from landless labour households getting a job reaches an annual low of .20 during April.[14] Mechanical threshing may release women to spend more time on household activities, but it is questionable that the value of such activities could compensate for lost wages.

CROPPING INTENSITY

The machine threshing of hybrid sorghum in Kanzara can release family and bullock labour for sequential cropping in the postrainy season. The most common postrainy season crops are irrigated wheat and chickpeas. Wheat is planted on small plots irrigated by wells, and chickpeas are sown in low lying areas of fields. Thus seasonal rainfall and access to well irrigation are important determinants of double-cropping potential.

In order to test the hypothesis that threshers have increased cropping

intensity, two types of comparisons are made in Table 6. The first two columns record the percentage area and farmers in Kanzara planting different crop combinations during the rainy and postrainy seasons. If the cropping intensity hypothesis is valid, we would expect that more farmers allocated more land to sequential cropping and/or cropped more fallow land or leased-in land during the postrainy season in the last three years compared with 1975/76 before machine threshers were introduced.

TABLE 6

CROPPING PATTERN BY VILLAGE IN PERCENTAGE OF CULTIVATED AREA AND NUMBER OF FARMERS

Cropping pattern and season		Village: Kanzara Percent area	Village: Kanzara Percent farmers	Village: Kinkheda Percent area	Village: Kinkheda Percent farmers
Rainy season intercropping	1975-76	71	89	86	100
	1976-77	73	100	83	100
	1977-78	77	100	88	93
	1978-79	72	100	76	75
Rainy season sole cropping	1975-76	25	74	7	25
	1976-77	21	79	5	36
	1977-78	16	63	5	25
	1978-79	18	68	17	32
Rainy season sequential cropping	1975-76	2	32	3	18
	1976-77*	6	53	8	43
	1977-78	3	37	4	29
	1978-79	7	32	3	18
Postrainy season cropping on rainy season fallow or leased-in land	1975-76	2	16	3	11
	1976-77	0	5	4	18
	1977-78*+	5	47	3	18
	1978-79	3	32	3	14

* Statistically significant at the 5% level in the before-and-after comparison.

+ Statistically significant at the 5% level in the with-and-without comparison.

The data in Table 6 do not suggest a sharp change in cropping pattern. Nevertheless, a Wilcoxon matched pair signed-ranks test [*Siegel, 1956: 75–83*], which is suited to test statistically the changes in cropping pattern for 19 farmers who switched to mechanical threshers in 1976/77, indicates that sequential cropping in 1976/77 and postrainy season cropping on leased-in or rainy season fallow land in 1977/78 were significantly greater than in 1975/76. The other before-and-after comparisons do not yield statistically significant results at the five per cent level.

The small but statistically significant increase in postrainy season cropping could be due to other variables such as rainfall. Total rainfall received in Kanzara in 1975/76 was slightly above 500mm. In contrast, more than 800mm fell annually from 1976/77 to 1978/79. Wetter years favour more sequential cropping especially in low lying areas where chickpeas are grown.

Fortunately for our purposes, from 1976/77 to 1979/80 machines were not used to thresh sorghum in Kinkheda, a neighbouring VLS village. Contrasting the cropping pattern in Kanzara with that in Kinkheda establishes a with-and-without evaluation of the impact of mechanical threshing.[15]

The influence of weather is readily detected in the last two columns of Table 6. For the 31 VLS farmers who planted sorghum in Kinkheda from 1975/76 to 1978/79, percentage sequential cropping jumped from 18 in 1975/76 to 43 in 1976/77. Both villages received more than 800mm of rainfall in 1976/77, and a Mann-Whitney U test [*Siegel, 1956: 116–27*] shows that the distribution of sequential cropping is not significantly different for the two villages. A similar test on differences in postrainy season cropping in 1977/78 leads one to reject the null hypothesis that the two samples are drawn from the same population – more farmers allocated more land to postrainy season cropping in Kanzara than in Kinkheda.

Overall the evidence that mechanical threshing in and of itself caused a favourable impact on cropping intensity is extremely weak. In only one year has there been a significant increase in postrainy season cropping that could be attributed to machine threshing. And in that year postrainy-season cropping accounted for only five per cent of total cultivated area.

CONCLUDING COMMENTS

Because of few confounding effects, Kanzara offered an excellent vantage point to evaluate over time who gained and who lost from machine threshing. The main beneficiaries were machine owners, particularly the first owner who was able to profit from a strong demand for machine hiring without having to share throughput with other machines. Crop diversity and low production encouraged machine hiring as few if any farmers had enough produce to afford a lumpy investment like a thresher. With the entry of more machines into the village, excess machine capacity rapidly developed which eroded profitability and dampened investment incentives.

Skilled labour gained little at the expense of unskilled labour. A thresher is relatively easy to operate, and, unlike tractorisation, new occupational categories like thresher operator did not evolve with the introduction of machine threshing.

All farmers in the sample could and did hire in machines, but machine threshing was more widely used by farmers who produced more sorghum, planted proportionally more hybrids, cultivated more land, and had less draught power. Although use was substantial, producer benefits were not large. Machine threshing did not increase cropping intensity nor did it significantly reduce costs compared to traditional methods.

The four per cent in-kind fee charged by thresher owners has not been exorbitant, but the spatial oligopoly nature of the village threshing market suggests that the cost-reducing potential of mechanical threshing has only partially been realised. With present levels of cereal production in SAT India, only a few machines per village are economically feasible. A few machines per village do not lead to competitive pricing. Under these conditions, it is questionable whether potential benefits from reduced costs due to new threshing technologies will be passed on to producers and consumers.

The principal losers were male hired labourers who were displaced by machine threshing; however, a diversified output mix mitigated the potential adverse impact on male hired labourers' welfare. Because cotton is the dominant crop in Kanzara, we did not see marked labour displacement at the village level from machine threshing of sorghum. We would expect to see much greater labour displacement in rainy-season fallow, postrainy-season sorghum-growing regions and in machine threshing of pulses, that traditionally requires a large amount of female labour at the start of the summer season when wage employment is much harder to find.

The argument that machine threshers may break labour bottlenecks that constrain multiple cropping is diminished by the multiplicity of cropping patterns in dryland agriculture. Illustrative calculations on one potential sequential cropping pattern, may greatly overestimate and disguise the nature of seasonal labour bottlenecks.

The demand for improved threshing technologies could increase *if* investment in irrigation opened up more opportunities for multiple cropping, *if* short-duration, mould-resistant rainy season sorghum hybrids and varieties were developed to enhance the potential for sequential cropping, and *if* hulling characteristics of high-yielding, difficult-to-thresh sorghum cultivars could not be upgraded through plant breeding. Moreover, *if* there was scope for significantly enhancing the field performance of machines supplied by the private sector, public research could yield dividends. Thus the payoff from public investment in research on mechanical threshing is extremely problematic in dryland agriculture.

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NOTES

1. Singhal and Thierstein cite a 1978 version of the Ghodake *et al.* paper.
2. Comparative advantage refers to the incentive structure in the private sector to carry out mechanisation research and to the skills required to identify relevant researchable problems and to arrive at cost-effective solutions. Based on historical analyses of mechanical innovations, Binswanger [*1982: 40–41*] and Ruttan [*1982: 186–92*] convincingly argue that the public-goods character of biological research is much greater than that of farm machinery research.
3. Mechanisation often occurs simultaneously with increased use of other inputs such as fertiliser and irrigation. With-and-without comparisons are sensitive to the confounding effects of changing management practices; before-and-after comparisons do a better job in establishing causality when management practices change but they are susceptible to confounding from weather variability. Taken together, the two types of comparisons are characterised by fewer confounding effects than either taken separately.
4. Four of the five owners are large farmers who belong to higher castes. The five owners have on average nine years of schooling; the village average for male heads of household is three years.
5. Compared to local sorghum, both hand beating and bullock treading for threshing hybrids used relatively more hired than family labour. This may be one reason for the popularity of machine threshing for hybrids. Expectations of post-harvest damage from rainfall may also contribute to why machine threshing is favoured for hybrids. Although this is a plausible explanation, the expected probability of a wet week for most of the threshing season is not

large. There is a greater chance of inclement weather during October when hybrid sorghum is threshed than during December, the peak month for threshing local sorghum. The average probability of a wet week is about .16 during the peak two fortnights of hybrid threshing in October; a comparable estimate for local sorghum threshing during the peak two fortnights in December is .06 [*Virmani et al., 1978: 20–21*].

6. The estimates in Table 3 are obtained by multiplying the coefficients in Table 2 by the average cropping year price and wage data reported in Asokan [*1980: 3, 4, 6, 9, 11*]. The same wage rates are used for family and hired labour. The wage estimates (constructed from Ryan *et al.* [*1979*]) underlying the cost analysis in Table 3 are based on annual averages by operation. The results do not change when we substitute estimates of the seasonal opportunity cost of labour for the annual averages.
7. We assume that multiplying the sampled farmers' production by the reciprocal of the sampling fraction (27%) gives total production in the village from 1975/76 to 1979/80. Assumptions on the machine are an initial purchase price of Rs. 6,500, an operating cost of Rs. 15.38 per 8-hour day, a labour charge of one man-day to the machine owner, no maintenance expense, a useful life of six years, a zero salvage value, nontransferability of machine parts such as the motor, and a fixed 4% in-kind payment of threshed grain. Sorghum and wheat are priced at Rs. 100 and 145 per quintal. These assumptions approximate 1975/76 when the first thresher was purchased in Kanzara and are supported by survey evidence on machine utilisation in Kanzara. Based on this evidence and these assumptions, the only machine that worked in the village in 1976/77 threshed about 80,000 kgs. of sorghum. In 1977/78, two threshers operated in Kanzara, and they each threshed only about 40,000 kgs. of sorghum. Clearly, there was excess capacity in 1977/78 with the introduction of just one more machine.
8. Post-harvest operations include drying, husking, threshing, winnowing, and cleaning [*Binswanger and Jodha, 1978: 115*].
9. To a limited extent, the reduction in numbers in Table 4 could be attributed to fewer rounds or interviews in the later crop years. The frequency of rounds during the sorghum threshing season declined from 8, 7, 5, and 4 in 1975/76, 1976/77, 1977/78 and 1978/79 respectively.
10. Four members left their households in the village and one died.
11. This estimate comes from multiplying the male hired labour use coefficients in Table 2 by proportions used in each threshing method to derive a weighted male hired labour use in hours per quintal which, in turn, is multiplied by total production and divided by total male hired labour hours in cropping activities during the fortnight to give percentage male hired labour use in threshing sorghum.
12. Based on 1975/76 production and 1977/78 adoption levels.
13. Based on data from 493 pulse fields from 1975/76 to 1978/79, hired females contributed about 30, 35, and 45 per cent of the labour required to thresh mung-bean, black-gram, and pigeonpea respectively.
14. This calculation is based on fortnightly data and follows the methods used in Ryan and Ghodake [*1980*].
15. Only two rounds of employment data were taken in Kinkheda during 1977/78; therefore, it is not possible to carry out a with-and-without employment comparison for the two villages. Nevertheless, for 1975/76 and 1976/77, 14 and 8 sorghum daily threshing observations were reported in Kinkheda; the rate of involuntary unemployment was 6% for 1975/76 and 0% for 1976/77. The latter rate is significantly ($p<0.05$) less than that reported for Kanzara in Table 5 for the same crop year.

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