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Can mechanization in agriculture help achieving sustainable development goals?

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Abstract This paper examines the spatial and temporal patterns in the cost of production for major crops, its determinants and potential in enhancing farm incomes. Specifically, it examines whether farm mechanisation can help reducing the cost of production (COP) in agriculture. The data were compiled from the 'Comprehensive Cost of Cultivation Scheme' of the Government of India, and covered 8 major crops among cereals, pulses, oilseeds, and commercial crops. It is found that COP grew between 2004-05 and 2014-15 with mechanisation but declined with increase in the human labour and yield. The results, though corroborate the findings of other studies on the subject, are seemingly contrary to our expectations. Higher level of use of farm machinery as revealed by the Input Surveys of the Ministry of Agriculture and Farmers Welfare, Government of India, could partly clear this contradiction. It may also be explained by an inelastic substitution of machine use for human labour and incompatibility of the type of farm machinery along with the existing format of custom hiring with land holding structure. Making available professional custom hire services that can ensure timely and dependable services through schemes like Custom Hire Centres (CHS) and start-ups may shape the future of farm mechanisation.

Keywords Cost of production, Mechanisation, Sustainable development goals

JEL classification D24, Q01, Q160, Q180, I380

1 Introduction

Improvements in agriculture hold the key to achieving the fundamental Sustainable Development Goals of 'No Poverty' (SDG 1) and 'Zero Hunger' (SDG 2). For agriculture to be sustainable and profitable, farmers must obtain better returns that can act as incentive for them to continue and do well in farming. The goal of doubling of farmers' income by 2022, announced by the Central Government in 2016, is a step towards this. Since major sources of income for farmers are crop and livestock farming, income enhancement from agriculture should come from increase in income as well as reduction in costs (Satyasai & Mehrotra, 2016). Some of the pertinent questions in this context are: What are the trends in income from different crops? Is there any decline in the cost of production? Has the cost composition changed and can offer any clue for future strategies to reduce it? Is there any pattern in farm mechanisation across crops and states and in relation to costs? Several scholars have attempted to answer these questions in the past.

In a very comprehensive study on costs and returns based on cost of cultivation data, Srivastava et al. (2017) observed that cost of cultivation per hectare in real terms increased between 1990-91 and 2014-15. Farm mechanisation is one of the means that can potentially change the face of agriculture and lead to decline in costs. It has proven potential to enhance farmers' incomes and reduce costs. It can save time taken for farm operations, improve cropping intensity, change cropping pattern towards high value crops, enhance yields and reduce drudgery (Singh 2015; Kishor & Mor 2001 a, b). However, machine labour has contributed 15% to cost inflation (Srivastava et al.

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2017). Human labour and machine use being inelastic substitutes, even when human labour wage increases in relation to machine use price, machines cannot substitute labour to the desired extent and hence, total cost would increase. Another issue is the suitability and adoptability of farm machinery on small and marginal farms. In that situation, the major option to reduce costs in agriculture is to improve crop yield.

Farm mechanisation has attracted considerable attention in debates in academic and policy circles because of its labour displacement potential in a labour surplus economy. Nonetheless, the spread of farm mechanisation has been phenomenal. While debates continues, farmers adopt machinery so much so that it is impossible to imagine farm operations without its use in some or the other farm operations. Narayanamoorthy et al. (2014) found that machine labour use in agriculture increased in paddy and wheat after introduction of employment guarantee scheme, Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS). The authors suggest that this phenomenon is probably due to desperate attempt to substitute human labour, which turned expensive and scarce after the MGNREGS and partly due to profit motive as machines would lead to higher productivity. Basu & Nandi (2014) conclude that higher use of machine labour relative to human labour tend to reduce unit cost in paddy and also improve returns on investment. Reddy et al. (2014) also observed increased use of machines replacing human and bullock labour. However, due to domination of smallholdings and lumpy investment requirement, most farmers must use machines on rent rather owning them. Thus, using machines on rent may need different arrangements at the field level.

In this background, this paper studies the spatial and temporal pattern in the cost of production and yields of major crops. it also examines the trend in the use of machine and human labour and whether higher use of machine labour affected cost of production.

2 Data and methodology

The study is based on data compiled from the 'Comprehensive Cost of Cultivation Scheme' of Commission for Agricultural Costs and Prices (CACP), Ministry of Agriculture and Family Welfare, Government of India for the period 2004-05 to 2014-15. Cereals (paddy, wheat), pulses (gram, arhar), oilseeds (groundnut, rapeseed and mustard), commercial crops (cotton and sugarcane) are covered in the study. Compound annual rates of growth (CAGR) are computed to understand the trends in cost of production and other costs and yields. The basic question explored in this paper is whether machine labour cost has any impact on cost of production besides other factors. Simple multiple linear equation is estimated using the Ordinary Least Squares (OLS) technique. The variables included are given in table 1.

Further, we explore the use of power operated farm machines (tractor, thresher, harvester) in agriculture from Input Survey for 2001-02 and 2011-12 conducted by Agricultural Census Division, Ministry of Agriculture and Farmers Welfare, Government of India at state and district levels. Then, based on literature, we discussed emerging models for farm mechanisation.

3 Cost of production

Cost of production is the unit cost of producing a given output. It is the measure of efficiency in production. In 2014-15, cost of production of paddy ranged from Rs.594/Q in Punjab to maximum of Rs.2155/Q in Maharashtra (table 2). For wheat, minimum cost of production was (Rs. 648/Q) in Punjab and maximum in Maharashtra (Rs. 1527/Q). In respect of other crops too, there was significant inter-state variation in the cost of production. The coefficient of variation (CV) ranged from 21% for groundnut to 39% for rapeseed-mustard. The cost of production taken is C2 which is based on cost A2 plus family labour cost, and is generally lower than the minimum support price (MSP) for that year. The cost was higher than the MSP for cotton in Haryana, Madhya Pradesh and Odisha, arhar in Andhra Pradesh, gram in Uttar Pradesh, and groundnut in Maharashtra, and rapeseed and mustard in Assam.

Table 3 shows trends in cost of production (based on C2), yield and machine labour cost for selected crops. Yields grew at a slower pace across crops, recording negative growth rates in a few states. Variation in growth rate in yield across states too is rather high across major crops. As we know, yield growth is the main pathway to lower the cost of production. Using technology like farm machinery can substitute labour that accounts for major share of cost and inflation

Table 1. Description of variables

Variables (growth rates)	Description	Expected sign of coefficient
COP	Dependent variable Rs/Quintal based on Cost C2#	
YIELD	Yield of a given crop in a given state, Quintal/ha	-ve
HLAB_HRS	Human labour input, Hrs/ha	+ve
MACH_COST	Cost of machine labour used, Rs/ha	- ve
YIELD*NORTH	Slope dummy@ for Northern region (Rajasthan, Punjab, Haryana, Jammu Kashmir, Himachal Pradesh, Uttarakhand)	+/-
YIELD*WEST	Slope dummy for Western region (Gujarat, Maharashtra)	+/-
YIELD*EAST	Slope dummy for Eastern region (Bihar, Jharkhand, Odisha, West Bengal)	+/-
YIELD*CENTRAL	Slope dummy for Central region (Chhattisgarh, Madhya Pradesh, Uttar Pradesh)	+/-
COMM_CROP	Intercept dummy@@ for commercial crops	+/-
PULSES	Intercept dummy for pulse crops	+/-
OILSEEDS	Intercept dummy for oilseed crops	+/-

Cost C2 = Cost A1 + rent on leased in land + interest on owned fixed assets other than land + rental value of owned land + imputed costs of family labour

@ Southern region, used as a base category, consists of Andhra Pradesh (combined), Karnataka, Kerala, Tamil Nadu. North Eastern region is not covered.

@@ Cereal crops is taken as base category

Table 2. State-wise cost of production of major crops, 2014-15 (Rs/Q)

State	Cereals		Pulses		Oilseed crops		Commercial crops	
	Paddy	Wheat	Arhar	Gram	Groundnut	Rape & Mustard	Sugarcane	Cotton
Andhra Pradesh	893		4610	2153	3424		148	3321
Assam	1153					3346		
Bihar	875	1036		1411		1356		
Chhattisgarh	938			2176				
Gujarat		1051	3665		3213	1426		2901
Haryana	911	842		1962		1686		4156
Jharkhand	882	1505		1299				
Karnataka	915		2724	1947	3639		91	3059
Kerala	1223							
Maharashtra	2155	1527	4189	2437	5014		146	3585
Madhya Pradesh	1151	801	2968	1943		1276		4624
Odisha	1178		4336		3275			5228
Punjab	594	648						2878
Rajasthan		1037		2636		1923		2948
Tamil Nadu	1127				2917		134	2974
Uttar Pradesh	1105	1265	2772	4166		2567	101	
Uttarakhand	644	934					79	
West Bengal	1247	1311						
Mean	1062	1087	3609	2213	3580	1940	117	3567
Minimum	594	648	2724	1299	2917	1276	79	2878
Maximum	2155	1527	4610	4166	5014	3346	148	5228
C.V. (%)	33.0	26.3	21.9	36.1	20.7	39.3	25.7	23.3
MSP (Rs/Q)	1360	1450	4350	3175	4000	3100	220	3785

Source: Computed from cost of cultivation data.

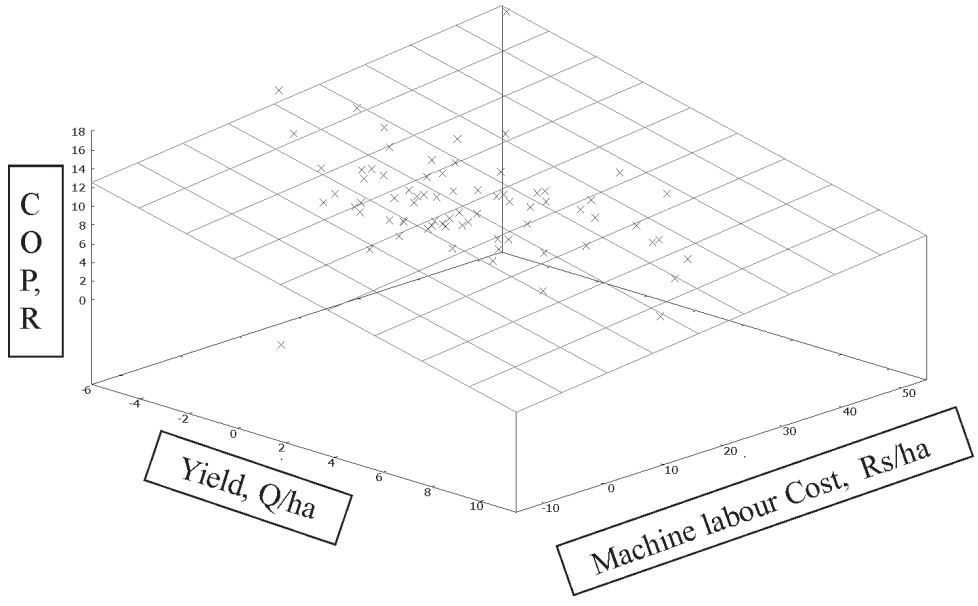

Figure 1. Relation between COP, machine labour cost and yield of crops
Source: Cost of cultivation data, CACP
Note: 3-D graph is generated using GRETL, an open source econometrics software

therein. Hence, we compare growth rates in COP and machine labour cost. In 4 out of 8 crops, i.e., paddy, wheat, rapeseed-mustard and sugarcane, the correlation between growth in cost of machine labour and cost of production is negative. In case of pulses, groundnut and cotton, the relation is positive. The relation between COP, machine labour cost and yield of crops across states is captured in a 3-D graph (figure 1) which shows an inverse relation between COP and yield, and a direct relation between machine labour cost and COP.

To understand the relation between the growth rates in cost of production and farm machine labour cost, we explored this relation further using linear functional form. The estimates are given in Table 4. Growth in COP is lower whenever yield growth was positive. Each one-percentage point increase in growth rate in yield can reduce growth rate in COP by 0.546 percentage point in southern states. Influence of yield on COP, however, is region-specific. One percentage point increase in yield growth rate can bring down COP growth by 1.117, 0.819, 0.778 and 0.654 percentage points, respectively, in eastern, central, northern and western regions. The impact of yield in eastern and central states is significantly different from that in southern states. That is, efforts towards bringing yield growth in eastern and central states would bring higher efficiency in crop production. The type of crop can make a difference to the growth in COP. Taking cereals as a base category, when one moves to commercial crops, pulses or oilseeds, the COP accelerates by at least 2.22 percentage points.

4 Level of use of farm machinery

Input Survey conducted by the Ministry of Agriculture and Farmers Welfare, Government of India every five years records number of operational holdings using various types of farm machinery. Here, we have taken major power-operated farm machinery, i.e., tractors, threshers and harvesters. We divided number of holdings reporting use of machinery by net sown area (NSA) to get the penetration of farm machinery. Here we ignored the possibility of some farmers using multiple machines. Table 5 gives state-wise penetration of machine use.

Around 171 holdings reported use of farm machinery at all India level in 2001-02. Higher number of holdings have used machines in Tamil Nadu (613) followed by Haryana (576), combined Andhra Pradesh (302) and Punjab (286). The penetration of machine use increased over 3.5 times during the decade to reach 594 at all India level by 2011-12. Chhattisgarh, Uttar Pradesh, Assam, West Bengal recorded highest increase in

Table 3. Compound growth rate (%) in cost of production, yields and machine labour cost, 2004-05 to 2014-15

State	Cereals						Pulses						Oilseeds						Commercial crops					
	Paddy			Wheat			Arhar			Gram			Groundnut			RM			Sugarcane			Cotton		
	C	Y	M	C	Y	M	C	Y	M	C	Y	M	C	Y	M	C	Y	M	C	Y	M	C	Y	M
Andhra Pradesh	10.4	1	17.6				16.3	-3	17.5	13.1	0.2	17.3	10.6	5.8	21.8				9.5	-0.6	16.7	11.4	0.1	17
Bihar	10.3	0.8	11.8	7.4	2.9	9.6	0.8	1.5	-13.4	9.5	1.9	14.8				3.7	5.3	15						
Chhattisgarh	9.8	2.5	26.8	6.5	4	11.9				12.3	-2.1	19.7												
Gujarat				10.3	0.1	11.2	14.4	-2.2	19.1				11.5	3.5	16.6	9.6	1.5	7.4				11.1	1	12.7
Haryana	10.3	-0.2	5.9	9.1	1.1	8.8				6.3	11.2	10.9				9.4	2.2	9	12	-0.6	12.1	12.5	-1	10.5
Jharkhand	9.2	1.5	23.9	2.5	5.5	38.5																		
Karnataka	10.1	0.4	13.9				9.8	3.3	21.2	10.9	3.2	22.7	11.8	4.5	18.8				10	-1.9	38.3	10.2	8.4	22.1
Kerala	8	3.2	21																					
Madhya Pradesh	5.9	8.7	23.3	7.6	5.2	15.5	11.9	1.6	22.9	10.4	1	14.7				7.7	3.7	15.9				6.4	2.6	18.6
Maharashtra				5.7	0	19.9	12.1	4.4	31.8	7.8	5.8	20.1	9.9	2.7	14.7				8.8	2.4	13.2	9.5	6.6	25.5
Orissa	11.9	0.5	17.9				11	-0.8					14.6	0.2	21.5							17.3	-5.4	52.8
Punjab	10.5	-0.2	6.8	7.6	1.1	8.2																12.4	-2.2	8.2
Rajasthan				8.5	1.7	10.2				9.2	1.9	13.1				12.1	-0.7	9.4				13	3.8	13.2
Tamil Nadu	8.6	1.4	12.7										13.2	0.9	18.3				10.2	0.2	4.9	8.7	4.8	9.8
Uttar Pradesh	9.1	2.5	13.9	9	0.6	8.4	15.4	-3.2	7.7	16.5	-5.7	15.4				12.4	-1	11.9	11.9	-0.4	3.5			
Uttarakhand	8.5	2	12.3	6.1	0.4	6.2													12.5	0.3				
West Bengal	10.4	1.5	19.7	5	5.3	33.6										7.4	3	30.8						
Mean	9.5	1.8	16.3	7.1	2.3	15.2	11.5	0.2	15.3	10.7	1.9	16.5	11.9	2.9	18.6	8.9	2.0	14.2	10.7	-0.1	14.8	11.3	1.9	19.0
Minimum	5.9	-0.2	5.9	2.5	0.0	6.2	0.8	-3.2	-13.4	6.3	-5.7	10.9	9.9	0.2	14.7	3.7	-1.0	7.4	8.8	-1.9	3.5	6.4	-5.4	8.2
Maximum	11.9	8.7	26.8	10.3	5.5	38.5	16.3	4.4	31.8	16.5	11.2	22.7	14.6	5.8	21.8	12.4	5.3	30.8	12.5	2.4	38.3	17.3	8.4	52.8
CV (%)	15.3	121.5	38.7	29.8	92.4	69.0	42.3	1457.2	95.2	28.4	245.9	22.7	14.4	72.6	14.8	33.7	114.3	56.1	13.3	-1530.7	85.1	26.0	225.1	68.8
Correlation with COP			-0.32			-0.79			0.66			0.26			0.50			-0.43			-0.34			0.53

Source: Computed by authors from cost of cultivation data.
Note: C : Cost of production based on Cost C2 (Rs./Q); Y : Yield (Q/ha); M : Machine labour cost (Rs./ha).

Table 4. Factors affecting growth rates in cost of production (COP)

Variable (growth rates)	Coefficient	Std. Error	t-ratio	p-value
Constant	9.120	0.447	20.440	<0.0001
YIELD	-0.546	0.119	-4.607	<0.0001
HLAB_HRS	0.353	0.063	5.612	<0.0001
MACH_COST	0.044	0.020	2.252	0.0278
YIELD*NORTH	-0.232	0.169	-1.377	0.1734
YIELD*WEST	-0.099	0.173	-0.574	0.5678
YIELD*EAST	-0.571	0.183	-3.116	0.0028
YIELD*CENTRAL	-0.273	0.157	-1.738	0.0871
COMM_CROP	2.218	0.567	3.911	0.0002
PULSES	2.237	0.544	4.109	0.0001
OILSEEDS	2.379	0.542	4.392	<0.0001
Mean of dependent variable	9.884	Standard deviation	2.966	
R-squared	0.761	Adjusted R-squared	0.724	
F(10, 63)	20.104	P-value(F)	4.84e-16	

No. of observations n = 74

Table 5. Penetration of farm machine use in agriculture across states

State	Farm Machine use level (No. of holdings using machines per 1000 ha NSA)			Term Credit/1000 ha NSA (Rs. Lakh)		
	2001-02	2011-12	Growth (%)	2001-02	2011-12	Growth (%)
Andhra Pradesh	302	697	131	9.4	20.8	120
Assam	9	47	422	1.2	8.2	596
Bihar	-	3780	-	-	31.1	-
Chhattisgarh	16	297	1756	0.0	5.3	-
Gujarat	106	163	54	7.9	31.2	295
Haryana	576	464	-19	45.5	567.1	1148
Himachal Pradesh	63	116	84	4.3	244.6	5577
Jammu & Kashmir	253	1185	368	0.0	21.1	-
Jharkhand	-	478	-	-	23.9	-
Karnataka	64	175	173	20.8	31.9	54
Kerala	133	88	-34	46.8	385.5	723
Madhya Pradesh	146	336	130	3.3	14.2	333
Maharashtra	37	167	351	7.6	29.5	289
Orissa	128	399	212	3.4	10.3	204
Punjab	286	296	3	32.7	234.9	619
Rajasthan	215	516	140	11.5	49.6	331
Tamil Nadu	613	970	58	23.9	83.3	248
Uttarakhand	116	197	70	0.0	39.6	-
Uttar Pradesh	162	1068	559	6.5	10.3	58
West Bengal	150	747	398	4.8	11.3	136
All India	171	594	247	10.7	14.3	34

Source: Compilation based on data from Input Survey 2001-02 and 2011-12 accessed from www.agcensus.nic.in

machine use in the decade. In 2011-12, penetration of farm machine use per 1000 ha of NSA is highest in Bihar (3780) followed by Jammu & Kashmir (1185) and Uttar Pradesh (1068).

5 Recent innovations in spread of farm mechanisation

From the previous discussion, it emerged that increase in machine labour cost enhanced the cost of production of crops across crops and regions. However, evidence from successive input surveys shows that level of farm machinery use has increased in both penetration and diversity. That is, farmers find it advantageous to go for farm mechanisation. Preference for mechanisation is reflected in the annual growth of 8- 9 per cent in sales of tractors and power tillers in India between 2004-05 to 2016-17. Also, the Indian farm mechanization market, which was valued at Rs.320 billion in 2015-16, is expected to grow at 5.74% a year to reach Rs.400 billion by 2019-20 (Indian Council of Food and Agriculture, 2017). Possibly, we need to work on different models and formats of enhancing adoption of farm mechanisation to suit land holding structure.

Farm mechanisation has been promoted through credit support overtime and demand for tractors is highly elastic to bank credit (Singh 2015; Kishor & Mor 2001a). NABARD has provided refinance support (table 6) to farm mechanisation which grew at an annual rate of 12.75 per cent. This might have encouraged purchase of tractors and other equipment by farmers.

As observed in table 5 earlier, there has been an improvement in the level of machine use. When we juxtapose with term credit obtained by farm holdings, there seems to be weak relation between the two. This does not mean that credit is not important for growth of farm mechanisation. Over time, due to interest subvention on crop loans, credit access became very cheap and hence there is growth in short term credit relative to term loans. Though farmers might allocate part of crop loans towards purchase of machinery, that will not be reported as term credit. Further, financing farm machinery especially tractors, is partly decoupled from formal banking system as Non-Banking Finance Companies often promoted by the tractor manufacturers themselves took lead. Thus, term credit reported forms only a part of tractor financing.

Table 6. Refinance for farm mechanisation from NABARD: 2001-02 to 2017-18 (Rs. crores)

Year	Total refinance	Refinance for farm mechanisation	Share of farm mechanisation in total refinance (%)
2001-02	6683	1359	20.33
2002-03	7418	993	13.38
2003-04	7605	828	10.88
2004-05	8577	1055	12.30
2005-06	8622	1713	19.87
2006-07	8795	1858	21.12
2007-08	9046	1748	19.32
2008-09	10535	1514	14.37
2009-10	12009	1715	14.28
2010-11	13486	1763	13.07
2011-12	15422	2135	13.84
2012-13	17674	2283	12.92
2013-14	21486	3062	14.25
2014-15	31427	2384	7.58
2015-16	48064	5672	11.80
2016-17	53506	11076	20.70
2017-18	65240	6862	10.52
CAGR %	14.90	12.75	

Source: Annual Reports of NABARD.

Financing of tractors and other machinery by banking system is done following certain norms to ensure the viability and bankability. These norms presume operating minimum landholding with irrigation facilities. Thus, farm machinery requiring lumpy investments remained beyond the reach of small and marginal holders. However, given the labour shortage during peak season and advantages of mechanisation such as labour saving, time saving and ensuring deep ploughing and so on, all sections of farmers have keen interest in using machines on custom hiring basis leading to a win-win situation. Bullock labour use for farm operations diminished over time from 14 per cent of the cost in TE 1990-91 to 5 per cent in TE 2014-15 and share of machine labour reversed from 7 per cent to 14 per cent (Srivastava et al. 2017).

While the custom hiring has developed as a mode to extend use of machinery beyond their owners, the arrangement is highly localised and informal which imparts uncertainty in getting the service and also resulting in high rentals. Earlier, the Government of India started Agro Service Centres in 1971 that provided machines on custom hire. During the 12th Five Year Plan, custom hiring got a big push through the launch of Sub-Mission on Agricultural Mechanisation under the umbrella of National Mission on Agricultural Extension and Technology (NMAET) and Rashtriya Krishi Vikas Yojana (RKVY). Both these programmes together helped form 6108 Custom Hiring Centres (CHC) across the country between 2014-15 and 2016-17 even as more than half of these were started in Andhra Pradesh and Telangana.

A recent study on the effectiveness of Custom Hiring Centres (CHC) in advancing farm mechanization (NABARD 2015) in four states viz., Punjab, Gujarat, Madhya Pradesh and Andhra Pradesh found most of the entrepreneurs in Gujarat and Madhya Pradesh belonging to the medium and large farm categories, while more than 50% of the entrepreneurs in Punjab and Andhra Pradesh belonged to small and marginal farm categories. The custom hiring centre model varies from state to state in terms of amount of subsidy provided, disbursement mechanism and additional services offered by the custom hiring centre. More than 60% of the operations mechanised were land preparation, sowing and harvesting. Farmers were able to use various implements and machines during peak season.

Many farmers in Andhra Pradesh and Gujarat availed the services of CHC despite owning machines and implements, primarily to use additional machines for seasonal usage. Farmers even reported having sold off additional farm implements and machines and availed those available with the CHC. This helped them to avoid maintenance and repair costs. Farmers did not have any issue of paying the rent for machines and implements. Instead, they found rental charges reasonable. Other than CHCs, machines are available on rent either from other farmers (who own the machines and implements) and/or private players who provide similar services. Factors such as quick and efficient service; saving on time and labour cost were key drivers for availing services from CHCs. Many farmers availing services reported having benefited from the CHCs in terms of timeliness and efficiency and thereby saving on costs. Their yields and incomes also improved.

FASAR (2016) observed that the custom hiring is the only practical way to introduce capital intensive, high quality mechanization to small farming structures in India. The custom hiring model enabled new machines to be used at their maximum capacity and enabled farmers to gain access to technology they otherwise would not have and be able to afford. The increased demand from processors has implied that the quality standards of the agricultural produce are continuously being driven higher, thus, creating a need for higher performance and more precise mechanization.

Custom hiring can significantly facilitate diversification in agriculture specifically from wheat and paddy to other crops. Machinery required for operations like sowing, planting, transplanting, plant protection, and harvesting and product recovery is highly crop specific. Severe labour shortages in crops such as sugarcane necessitates the use of machines such as sugarcane harvesters and planters. However, the cost of the equipment makes them unviable even for large farmers in India. Further, they need a minimum number of 1200 to 1800 operating hours annually to be financially viable. However, custom hiring through private entrepreneurs or co-operatives could help overcome these constraints and enhance their economic viability through better capacity utilisation. Thus, custom hiring holds an immense potential to change the farm mechanization culture in India.

Apart from the CHCs, innovations such as 'Uberisation' in farm machinery hire market and several start-ups that introduced professionalism in service provision are revolutionising farm mechanisation. We discuss a few innovations in this space here (Kedia 2018). As the rental market for tractors and other equipment is estimated to be anywhere between Rs.15,000 crore to Rs.70,000 crore (Alam 2016), one can understand why several players are trying to enter this space. These innovations use technology-enabled solutions and Internet of Things (IOT). One start-up is **forMart** which links owners of equipment with those who need instead of investing in buying new equipment. They reach out to farmers by organising roadshows, self-help groups, and through gram panchayats. Till date, they have covered 300-plus villages and have over 1,500 farmers on their platform.

Oxen Farm Solutions provide tech-enabled farm mechanisation solutions for a range of services including crop residue management, land preparation, planting, crop management, harvesting, and post-harvest processing. They use IoT, satellite imagery and big data analysis to gather information and analyse machinery performance, crop health, crop progress, and harvesting status.

Mahindra and Mahindra Ltd, India's largest tractor maker company, launched **Trringo** in 2016 to rent farm equipment to farmers across India at affordable prices. Trringo has set up a mobile app and a toll-free number where farmers can place their order as needed. A well-maintained tractor with a professional driver is provided. Till date, over 1 lakh farmers from Karnataka, Maharashtra, Rajasthan, Rajasthan, and Madhya Pradesh have registered.

Ravgo, an agri-equipment rental marketplace, operates based on the idea of a sharing economy. It aims to bring access to modern technology for small farmers who cannot afford ownership of expensive machinery. The platform leverages internet technology to provide benefits of mechanical technology to small and marginal farmers. **Agroman** is a product and price discovery platform focused on agriculture implements. Another start-up in this space is **EM3 Agri Services** which adopted 'Farming as a Service (FaaS)' as a concept. Having realized that Uber-like model where modern, affordable farm technology services are provided on a pay-per-use basis and on demand works better, the start-up provided farm services for the entire cultivation cycle. They are present in three states, Rajasthan, Uttar Pradesh, and Madhya Pradesh.

With these and many more technology-enabled start-ups emerging in the agricultural service segment, farm mechanisation is bound to move beyond mere tractorisation and pervade all farm operations and enhance efficiency and incomes like never before.

6 Conclusions

The paper analysed the variations in cost of production across states and crops between 2004-05 and 2014-15 period using cost of cultivation data. It is observed that growth in human labour input (hours) and farm machine labour cost are major drivers in pushing growth in the cost of production upward. Increase in crop yields reduced the growth in cost of production. However, the finding is against our *a priori* understanding that farm mechanisation can push the cost of production down with its expected human labour substitution possibility and improving efficiency in farming. Also, use of various types of farm machinery by farm holdings has increased manifold over time as per data from input surveys or the past studies. It is a contradiction that farmers adopted farm mechanisation even as it can escalate cost of production. There are a few possible explanations for this seeming contradiction. One, the type of farm mechanisation adopted right now may not be suitable and hence, is not able to provide elastic substitution of human labour thus increasing the costs instead of reducing them. Two, while we attempted to model the crop and state-wise data for over a decade, we could not capture the cropping intensity effect of farm mechanisation on incomes and employment, which can be quite substantial. Third, custom hiring services as existing may not be efficient to provide quality mechanisation solutions that can effectively reduce unit costs. The paper recommends organised Custom Hiring Centres (CHCs) and technology-based solutions that can professionalise the farm mechanisation space. Evidence shows that they are very effective and promising in shaping the future of farm mechanisation in terms of intensity and diversity.

Disclaimer

[The views expressed are of authors alone. Usual disclaimers apply. The authors are grateful to the editorial suggestions which helped improve the paper]

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