Changing Inter-Sectoral Linkages: Role of Technology Adoption in Agricultural Growth

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Abstract

The paper has examined the changes in inter-sectoral relations as driven by the sectoral shares and sectoral growth patterns, and has traced the nature of linkages between agriculture and the rest of the economy in the changing context. The relation between use of technological inputs in agriculture and employment encompasses the socio-economic and technical links between inputs and outputs. In this context, the paper has examined by means of a case study, the role of bio-chemical technology in raising crop productivity and net incomes of farmers. Increasing output and profitability in the agriculture sector are the necessary precursors for strengthening the linkages between agriculture and the rest of the economy. The adoption of herbicide-tolerant (HT) technology has been found to reduce the cost of production through lower expenditure on herbicides, labour, machinery and fuel, despite charging of technology fees on the seeds. In this context, the paper has assessed the potential impact on agricultural productivity and net profits through the introduction of technology, viz., herbicide-tolerant (HT) cotton in sample farms across Gujarat. The findings based on secondary analysis and evidence based on a case study have categorically indicated the need for greater farm mechanization coupled with introduction of technologies that are labour saving if agricultural productivity has to be maintained and stepped up. Such an outcome would no doubt enhance agriculture-industry linkages in the production process and would also have favourable income effects giving a further boost to agriculture and industry.

Keywords: Herbicide-tolerant cotton, Agricultural labour-use, Agriculture-industry linkages, Gujarat.

JEL Classification: J22, J23, J31, R1, Q12, Q16.

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Introduction

The relation between use of technological inputs in agriculture and employment encompasses the socio-economic and technical links between inputs and outputs. In the past, the spread of green revolution technology had led to the increased market dependence of cultivators for the supply of inputs (seed, fertilizers, farm chemicals, mechanized inputs) and for the sale of output. The access to factor markets by different groups of farmers was sometimes discriminatory and this was reflected in the intensity of employment problem faced by them (Ishikawa, 1981). Total labour utilization and composition of labour (i.e. family or hired) is also dependent on other factors such as decline in tenancy or concentration of land ownership noted in the agriculturally developed regions.

According to Bartsch (1977), switching from traditional to mechanized farm techniques (with technology remaining the same) is labour displacing. Mechanization of farm operations and technological innovations occur when the biological sources of energy (human and animal labour) become costlier than mechanical sources. A secular tendency thus exists due to the labour-saving bias of technological change as well as the increasing ease with which capital can be substituted for labour in agriculture and also due to the rise in cost of human labour. The technological progress contributes to reducing the cost on machines and fuel. On the other hand, the economic development and rising per-capita incomes raise the cost of labour through increasing demand for labour in the non-agricultural sector.

When agricultural mechanization is associated with the use of HYV technology, there is a lack of conclusive evidence on the changes in employment (i.e. labour input per unit of cultivated area) with altering technology (bio-chemical) and technique (tractors). While literature substantiates that HYV technology absorbs more labour, the role of mechanization is debatable due to confounding effects. However, with expansion of output, uncertainty with regard to availability of required labour for crucial farm operations raises the *ex-ante* costs for large farmers. They thus require mechanization for ensuring timeliness of operations and to insure against the uncertainties of hired labour.

It is also true that structural change or the re-allocation of labour from lower productivity activities (such as traditional agriculture) to higher productivity employment (such as manufacturing) drives economic growth. The rural and particularly agricultural face of India is undergoing dynamic transformation. The different facets of this process include rural resurgence and economic prosperity, increase in rural non-farm activities, as also the existence of distress, manifesting in terms of widespread hunger and malnutrition or even suicides. An examination of the employment structure shows that agriculture absorbed 78.4 per cent of the rural workers (UPSS) in 1993-94, but the share declined to 64 per cent in 2011-12. The rural manufacturing employment hovered around eight to nine per cent during this period. While agriculture continues to be the dominant source of rural livelihoods, the two sectors registering highest increase in workforce in the recent decades were construction, where the share of workers increased from 2.4 per cent to 11 per cent and trade, hotels and restaurants recorded increase in employment share from 4.3 per cent in 1993-94 to 6.5 per cent in 2011-12. The females continue to be engaged largely in the agriculture sector. This can be noted from the fact that in 1993-94, the share of agriculture in employment for males was 74.1 per cent, and for females was 86.2 per cent. In 2011-12, the share for males declined sharply to 59 per cent, but less so for females to 75 per cent. This shows that female labour force is finding fewer livelihood options outside agriculture. However, regional patterns do exist in the male-female distribution of activities in the rural areas across the country.

With the average farm size halving to 1.2 ha between 1970-71 and 2010-11, the rural landscape has witnessed a considerable transformation. Declining farm size, aspirational

changes and increased opportunities through infrastructure development, have resulted in diversification of portfolio of occupations of typical farm households. Diversification of livelihoods or 'deagrarianzation' is part of the wider process of rural transformation (Singh, 2007; Reardon, 1997). Shifting out of agriculture-related jobs is triggered by the village level factors such as fragmentation and polarization of holdings, dispossession from access to land/landlessness, indebtedness, average size of holding, and commercialization of agriculture (as cause and consequence) (de Haan, 2011). Migration to non-farm rural occupations of semi-urban and urban centres for supplementing family incomes, and a combination of on- and off-farm works and leasing-out of land have all dramatically changed the output composition of agriculture in the recent decades.

Under the above background, the present paper has examined the changes in inter-sectoral relations as driven by sectoral shares and sectoral growth patterns, and has traced the nature of linkages between agriculture and the rest of the economy in the changing context. Increasing output and profitability in the agriculture sector are the necessary precursors for strengthening the linkages between agriculture and the rest of the economy. In the subsequent section, hence, we have examined by means of a case study, the role of bio-chemical technology in raising crop productivity and net incomes of farmers.

Sectoral Shares, Growth and Inter-linkages

The Indian economy has undergone a significant transformation, and the production linkages between the commodity producing sectors, viz., agriculture and industry, have also witnessed considerable changes. We have assessed these changes in the inter-sectoral relations through changes in the sectoral shares of national income and the sectoral growth rates.

Table l. Percentage shares in GDP of three major sectors in India, 1970-2010 (at constant prices)

Year	Agriculture and allied sector	Industry	Services
1970-71	46.3	15.6	38.1
1980-81	39.7	17.6	42.7
1990-91	32.2	21.7	46.1
2000-01	21.0	21.8	54.2
2010-11	14.6	27.9	57.5

Source: Calculated from CSO data for various years

Sectoral Shares

It can be observed from Table 1 that in the three decades from 1971 to 2001 the share of agriculture and allied sectors had nearly halved from 46 to 21 per cent and in the previous decade it slid further from to 14.6 per cent (2010-11). The rural employment on the other hand is a different matter and agriculture still accounts for the largest share of employment. Clearly the productivity in agriculture and allied activities is quite low and this duality marks the economic transition process that requires a course correction through technological changes. The share of services sector in the national income has increased consistently. The industry also gained though only modest from 16 per cent in 1970-71 to 22 per cent in 2001 and rose sharply to 28 per cent in 2010-11. Evidently its record has not been too steady. The changes in the sectoral shares were gradual up to 1980-81. With the onset of economic reforms, there was a dramatic decline in the share of agriculture from 32 per cent (in 1990-91) to 14.6 per cent in 2010-11. During this period, there was a pronounced rise in the share of services from 46 to 58 per cent, while gains in industry were somewhat modest from 22 per cent to 28 per cent per cent

of the gross domestic product (GDP).

Sectoral Growth

The existence of a relation between structure of economy and growth process has been empirically verified (for example, in Cortuk and Singh, 2011; 2015). The sectoral shares are determined by the relative sectoral growth rates. Table 2 shows the annual trend growth of different sectors from 1970-71 to 2012-13. The sectoral growth pattern reflects that the performance of all the sectors was reasonably good during the 1980s (over the 1970s) contributing to a GDP growth of 5.2 per cent. In the 1990s, the GDP growth rate was higher than in the 1980s, but was driven by the tertiary sector. The industrial growth rate has been relatively high in 1980s and 1990s (around 6%), corresponding to relatively high agricultural growth rate of around 3.1 per cent. Similarly, the low growth rate in the industrial sector in the 1970s was also accompanied with low growth in the agriculture sector. This points towards the existence of close linkages between these two sectors. Departing from the long-term trend, in the 2000s-decade the growth in the industry sector accelerated to the unprecedented rate of 8.2 per cent, but the agriculture sector growth rate decelerated and hovered around 3 per cent. In fact, the trend in the beginning of the current decade shows that while agriculture sector growth has picked up at 4.8 per cent, industry has suffered a setback and growth has slowed down. The experience of the past two decades reveals a weakening of the inter-sectoral relationship. It can be noted that the growth rates of commodity-producing sectors, especially of industry have been volatile, but the growth rate of services has shown a continuous acceleration. The response of agriculture to favourable climatic conditions is also evident, as is its changing nature with greater emphasis on high-value and remunerative crops that are more amenable to processing.

Table 2. Growth rates of GDP in three major sectors in India (at constant 2004-05 prices)

Period	Agriculture	Industry	Services	GDP
1970-71 to 1980-81	1.81	4.29	4.47	3.38
1980-81 to 1990-91	3.10	5.82	6.58	5.18
1990-91 to 2000-01	3.1 1	5.92	7.60	5.94
2000-01 to 2009-10	2.91	8.19	8.80	7.56
2009-10 to 2012-13	4.79	5.41	7.28	6.40

Source: Calculated from CSO data for various years.

Agriculture-Industry Linkages

We next examined the long-term changes in the production linkages between agriculture and the rest of the economy, mainly the industry sector, to lend credence to the above findings. The production linkages between agriculture and industry arise from the inter-dependence between the two for meeting the production inputs. Agriculture is the source of inputs for many industries, notably cotton textiles, sugar and agro-processing sector. Agriculture absorbs industrial products such as farm chemicals, agricultural machinery, fertilizers, irrigation pump-sets, etc. The consumption linkages between the two sectors are defined by an increase/decrease in the consumption of industrial goods and services with enhancement/decline in agricultural incomes.

Table 3. Agriculture-industry production linkages: Input requirement/unit of output

Period	Agriculture	Industry
1979-80		
Agriculture	0.160	0.130
Industry	0.068	0.345
1989-90		
Agriculture	0.166	0.042
Industry	0.144	0.373
1993-94		
Agriculture	0.145	0.035
Industry	0.140	0.365
2003-04		
Agriculture	0.196	0.028
Industry	0.180	0.455
2007-08		
Agriculture	0.169	0.082
Industry	0.150	0.398

Source: Kashyap (2012).
For 2007-08: Input-Output Tables, 2007-08, CSO.

The production linkages between the economic sectors can be captured from the Input-Output tables published periodically by the Central Statistical Office. We have used information from the Input-Output tables for various points of time to depict the inter-dependence between the two sectors through the input-use pattern per unit of output. This is shown in the Table 3. In 1979-80, to produce a unit of output in the agriculture sector required 0.160 units from itself and 0.068 units from industry. Over a period of nearly thirty years, the input proportion from industry has increased nearly one and a half times (from 0.068 in 1979-80 to 0.150 in 2007-08). On the other hand, to produce one unit of industrial output, industry in 1980 required 0.130 units from agriculture and 0.345 units from itself. While the dependency of industry on itself in the longer time span increased further (from 0.345 to 0.398 units in 2007-08), the picture altered considerably vis-a-vis agriculture sector. There was a sharp decline in the dependence on agriculture, requiring 0.028 units for a unit of industrial output up to 2003-04. The reduced dependence of industry on agriculture could be attributed largely to the decline in the share of agro-based industries in the economy. It is apparent that industrial sector is becoming more broad-based and diverse, leading to a decline in the dependence of agriculture as a source of inputs, manifested in the weakening of industry-agriculture linkages.

However, from 2003-04 to 2007-08, the input requirement for industrial sector from agriculture has showed an upward trend from 0.028 to 0.082 — nearly a three-fold increase. It is possible that the weightage of agro-processing sector such as food-processing (both crop and animal husbandry based), textiles, etc. enhanced in the industrial output. As compared to 2003-04, some welcome changes have taken place in the industrial economy, such as increased dependence on industry of agriculture for inputs (notably hybrid seeds, farm chemicals), fertilizers, and machinery. Secondly, the dependence of industry on itself is reducing, which is indicative of the fact that agro-processing sector is forging ahead in the era of structural reforms. In the recent times, the entry of multi-national companies has been noteworthy, and has been an important factor aiding the shift in the rural and urban consumers' preference to processed agricultural commodities. However, we may add that such trends require further in-depth investigation. Also notable is the fact that the per unit dependence of agriculture on services has increased from 0.016 in 1968-69 to 0.023 in 2007-08. In this context we quote the following:

> "The development of agriculture through high productivity growth is usually emphasized because of its beneficial effects in terms of productive employment in agriculture, poverty removal and also giving fillip to the non-farm sector. This is no doubt true. For instance Dholakia and Sapre (2011), note that the high growth of agriculture in the recent decade in Gujarat is achieved through significant diversification in cropping pattern, from low-value to high-value commercial crops, with rapid increases in allied activities, such as dairying, fishing and horticulture. Favourable outcomes of this growth include reduction of poverty and consumption inequality and slowing down the structural shift in favour of non-primary sectors. Apart from these favourable outcomes, it needs to be emphasized that despite falling share of agriculture in the GDP, the agriculture sector plays an important role in determining the overall growth rate of the economy through its linkages with other sectors. These linkages no doubt should be strengthened by further modernizing the agriculture sector. Also, it is important that agro-based sectors are given a boost because of their high labour intensity and for providing inducement for agricultural growth." (Kashyap, 2012, p.23).

Rural Incomes

The slow growth in agricultural incomes is leading to the growing disparity between the per worker agricultural and non-agricultural incomes. Low net income from the agricultural sector has been cited as the primary reason forcing the farmers to abandon agriculture. Several attempts have been made to estimate farm incomes based either on sample of farmers or segment of agriculture (Narayanmoorthy, 2006; Sen and Bhatia, 2004). Data shortcomings notwithstanding, nearly all the researchers have reported that the income per farmer on an average was quite dismal. Chand *et al.* (2015) have alluded to various criteria that are being used as evidence to prove the decline in farm incomes, such as gap in input-output prices, growth in output and wages, and indebtedness. They have estimated farm income for the period 1983-84 to 2011-12 by subtracting the wage bill for hired workers in agriculture and allied sectors from the net domestic product of the sector. From 1983-84 to 2011-12 the cost of agricultural production increased at a higher rate when the labour cost was included in it. The study has traced the components of agricultural output (i.e. input costs, wages and farm income) and has shown that the initial shift of labour away from agriculture may not result in higher wage rates, but ultimately it leads to higher labour productivity and wage rates, as seen from the rise in the share of wages in output. The wage bill for hired workers comprised 26 per cent of total cost in 1983-84 and it rose to 36 per cent by 2011-12.

Table 4. Trend in growth in farm income, output and wages, 1983-84 to 2011-12

Particulars	1983-84 to 1993-94	1993-94 to 2004-05	2004-05 to 2011-12
Agricultural output (2004-05 price)	2.46	2.44	4.20
Input costs (2004-05 price)	2.03	2.27	4.05
Wage rate	3.46	2.46	6.54
Number of agricultural labourers	2.39	-0.28	-2.40
Days of employment of hired labourers	0.58	-0.59	0.06
Wage bill (deflated by CPIAL 2004-05)	6.49	1.61	5.80
Farm income (deflated by CPIAL 2004-05)	3.67	3.30	5.36

Source: Derived from Chand *et al.* (2015)

The growth in farm incomes is determined by the growth in output and also the rate of change in the cost of inputs, wage rates, number of hired workers and their days of employment, apart from the prices of agricultural commodities. The high growth in output and rise in farm income are accompanied by the rise in wage earnings; but for the latter to happen it is essential that the labour intensity in agriculture declines, as has been reported after 1993-94 (see Table 4).

The labour in agriculture is becoming expensive and wage component is increasingly eating into the net incomes from cultivation-related activities. This is perhaps the foremost underlying factor leading to the declining profitability and threatening the sustainability of agricultural livelihoods, even causing extreme rural distress. The shift of workers out of agriculture is a necessary pre-requisite for modernization of agriculture, for raising per capita wage earnings in the sector and for bridging the gap between the farm and non-farm incomes. The higher agricultural growth is also crucial for strengthening the linkages between the production sectors, as highlighted earlier. Keeping this in view, the rest of the paper, using survey based estimates of cost of cultivation for cotton, has examined the changes in net incomes and profitability as a result of agricultural modernization through the adoption of bio-chemical technology, more specifically labour saving transgenic cotton technology.

Agricultural Modernization and Profitability

The intensity of human labour use in agriculture is much higher in India compared to other nations. Labour scarcity and high labour costs are important issues in the current context of labour displacement due to urbanization. In the developed state of Gujarat this issue assumes somewhat greater relevance. Population pressure leads to changes in agricultural practices through innovations leading to adoption and diffusion of new agricultural technology. Technological progress and economic development with rising per capita income raise the cost of labour through increasing demand for labour in the non-agricultural sector. The prospect of saving on labour cost may also induce technology adoption in cultivation activities.

Labour is an important factor in the cultivation of cotton at different stages. Literature on the subject abounds with studies that use the production function approach to indicate the importance of labour input on marginal output value of cotton. Gross returns in cotton were highly responsive to the use of seeds and human labour. The labour-saving technological change can enhance the ease with which capital can be substituted for labour in agriculture. Also, the labour time saved is the opportunity income. A large number of econometric exercises have shown that adoption of genetically modified (herbicide tolerant) crops increased the off-farm incomes of farmers.[1] Several studies carried out for India have also shown that farmers adopting Bt cotton experienced remarkable cost saving and input-use efficiency, higher effective yields and net profits and thus, better economic performance. From the experience of Bt cotton in India and elsewhere it is apparent that the scale effects are neutral to technology adoption. The direct impact of Bt technology entailed a rise in cotton profits for all types of farm households, including those below the poverty line.

Amongst the challenges faced by Bt cotton farmers in the country (in addition to pest-infestation and abiotic stresses), foremost in the dry land areas is that cultivation is carried out largely by the traditional farm implements and labour shortages are frequent. Delay in the completion of peak-season operations, particularly weeding and picking often lead to yield losses. As such, weeds amount for a major loss in cotton crop — causing nearly 48 per cent of reduction in cotton yields. The cotton farmers fight weeds through tillage, hand weeding, herbicide application or through combination of all these measures. The physical method of weed control employing farm labourers, mostly women, is now considered a drudgery. The manual weeding in cotton farms is expensive and overall weeding outlays range between ₹ 7000 and 10,000/acre (Damodaran, 2011). The adoption of herbicide tolerant (HT) technology

[1] Fernandez-Cornejo, Hendricks and Mishra, 2005; Moschini, Lapan and Sobolevsky, 2000 to cite a few.

reduces the cost of production through lower expenditure for herbicides, labour, machinery and fuel, despite charging of technology fees on the seeds (Qaim, 2009; Qaim and Traxler, 2005; Pray *et al.,* 2001).

In this context we have assessed the potential impact on agricultural productivity and net profits of technological change through the introduction of herbicide-tolerant (HT) cotton in sample farms across Gujarat. The HT cotton is a labour saving technology (e.g., Monsanto's Bollgard Roundup Ready Flex).[2] In India, the adoption of HT technology is facing resistance on the grounds of impinging on livelihood opportunities of rural families. The rural poor workers and landless labourers find largest employment in manual de-weeding, apart from harvesting-related operations. It is believed that labour displacing agricultural technologies like herbicides and HT crops would reduce the existing employment opportunities. Within the cost of cultivation framework, we have estimated the labour use in Bt cotton production across size classes of cultivators, examined the total production cost of cotton output, including the share of hired labour cost and has compared the same with HT cotton samples. The results are based on a survey (2013) of around 350 Bt cotton farmers and adopters of HT seeds sold illegally in the state. The sample farmers were selected from seven cotton growing districts, namely Ahmedabad, Sabarkantha, Baroda, Bhavnagar, Surendranagar, Rajkot and Kutch in Gujarat. So far, the HT cotton crop has not been commonly reported in the small farm sector, as this category of cultivators largely carry out manual weeding with the help of family labour. Details of the sampling framework adopted and sample characteristics are available elsewhere (Mehta and Pareek, 2015) and are not reported here. The sample farmers were stratified as marginal, small, medium and large based on owned landholding.[3]

An opinion survey regarding challenges faced by the cotton cultivators was conducted and results showed that 80 per cent of the sample farmers considered weeds and overall labour scarcity to be the primary challenges in cotton cultivation, followed by availability of labour at reasonable rates (67%). Eleven per cent of the marginal farmers rated peak season labour scarcity as an important constraint. Cotton picking is a skilled operation and large landholders hire workers to carry out harvesting in a timely manner. Cotton picking and weeding operations are often assigned to groups of labourers who do the job on a piece rate manner.

During the peak cotton operations, the scarcity of labour was commonly reported. Only about 21 per cent farmers mentioned that skilled labour for hire was easily available locally. Nearly 42 per cent of the farmers indicated that getting labour for peak operations from within the village was an issue, indicating the magnitude of the problem. Further, only 38 per cent of farmers felt that sufficient labour was available from outside the village to carry out the crucial operations in a timely manner. Several reasons were cited for the inadequacy in availability of farm labour from within the village. Responses indicated the general conditions that led to the problem of timely availability of farm workers across the selected locations and are summarized in Table 5. It was seen, especially in the villages surveyed, that issues arising from non-farm diversification, city-wards migration, and urbanization caused the scarcity of labour for farm operations. It was clearly indicated that there was a need for greater farm mechanization coupled with introduction of technologies that alleviate the labour bottleneck if agricultural productivity has to be stepped up.

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[2] This type of cotton has reduced reliance on pre-emergence herbicides and imparts built in vegetative and floral tolerance to broad spectrum herbicides (e.g., glyphosate), spraying of which reduces the need for manual weeding in cotton. In India, this product is under various stages of field trials.

[3] Farmers owning less than 2.5 acres were considered marginal, between 2.5 and 4.9 acre small, between 4.9 and 25 acres medium and more than 25 acres as large farmers. The sample on the whole comprised marginal, small, medium and large farmers in the proportion of 9.5, 21.7, 56.6 and 12.3 per cent, respectively.

Table 5. Issues relating to labour scarcity

Issues	Percent responses
No problem	0.7
MGNREGA	8.8
Easy availability of non-farm employment	46.0
Lower wages in agriculture	9.7
Supply constraint due to peak season	14.3
Education and migration to cities/non-farm jobs (cities)	17.8
Others	2.8

Source: Primary survey

Further, a look into the herbicide sprays pattern of the sample farmers showed that small and marginal farmers comprised 12.7 per cent of cotton plots and 20 per cent of the sprays. The medium farmers accounted for 59 per cent of plots and 60 per cent of the herbicide sprays. The large farmers had a share of 28.4 per cent per cent of plots and only 20 per cent of the sprays. The average number of sprays per plot increased with size of holding (0.77 to 0.82) in the case of marginal and small farmers and declined to 0.51 and 0.36 for medium and large farmers, respectively. The average number of sprays per acre showed a progressive decline from 0.75/ acre for marginal holders to 0.04/acre for large cultivators. Thus, there is a distinct evidence of more intensive use of herbicides by smaller class-sizes. The small farmers largely use family labour for different farm operations. It may also be noted that marginal farmers often sell their labour or engage themselves in non-farm jobs for additional income. Hence they prefer to use herbicides rather than carry out manual weeding and employ themselves in jobs that fetch higher wages. The large farmers have to hire labourers for manual weeding and tillage operations.

Dynamics of Labour Use

With rural economy undergoing significant transformation, labour shortages are being experienced during peak agricultural seasons The farmers have to bear the increased burden of wages paid out for hired workers, which makes a significant dent in profits. All the respondents reported that variations existed in the wages paid to the hired workers during the period when demand for labour peaked. We next analyzed the labour absorption pattern for Bt cotton and HT cotton. For brevity, we have reported only the aggregate figures and not by region or size category of cultivators. The human labour (family and hired) was measured in terms of adult man-days (a day is equal to 8 working hours) and hired labour was derived by the summation of man equivalent days contributed by casual, attached and piece-meal labour. Labour days spent on tractor operations and supervision were also included.[4]

Table 6 presents the aggregate labour requirement and the extent of labour saved per acre in cotton cultivation with the adoption of HT cotton. The HT cotton showed labour saving by 17 per cent over the traditional Bt cotton hybrids. Out of this labour saving, the casual labour (including piece-rate workers) saved was to the extent of 43 per cent. Use of family labour in HT cotton, however, showed an increase by nearly 15 per cent. The entire increase in family labour was, on an average, accounted by the enhanced involvement of male family workers. Adoption of HT cotton led to the saving of 10 man-days of female casual labourers. The

[4] For computing man-days, the female and child labour was converted to man equivalent units by applying conversion ratios. For those operations where both males and females are being used, the conversion ratio of 1:0.67 was used, while for child labour, the conversion ratio of 1:0.50 was adopted. For some specialized operations, notably picking/harvesting and manual weeding, the conversion ratio of 1:1 was used for females and child labour (following Thorat, 2008).

involvement of male family workers showed an increase by 12 man-days. The male casual workers reported increase by seven per cent (3 man-days). If these estimates are scaled up for the rest of the country, the results will no doubt indicate that herbicide-tolerant cotton adoption in the dominant cotton-cultivating tracts is likely to make women free for undertaking non-farm jobs or for enrollment in the education system. The total dis-adoption of child labour as hired workers in cotton farms with the adoption of HT cotton was also observed. The main advantage of HT cotton stems from the use of less number of hired workers per unit of landholding.[5]

Table 6. Human labour-use in Bt and HT cotton, 2013
(man-days equivalent per acre)

Labour	Bt cotton	HT cotton	Change, %
	Family labour		
Male	57.9	70.0	21.0
Female	17.9	16.9	-5.4
Children	0.0	0.0	0.0
Total	75.7	86.9	14.7
	Casual labour*		
Male	43.2	46.2	6.9
Female	33.2	23.3	-29.8
Children	6.6	0.0	-100.0
Total	83.0	69.5	-16.3
	Permanent/Attached labour		
Male	16.0	0.0	-100.0
Female	11.6	0.0	-100.0
Children	1.5	0.0	-100.0
Total	29.1	0.0	-100.0
	Total labour-use		
Male	117.1	1 16.2	-0.8
Female	62.7	40.2	-35.8
Children	8.1	0.0	-100.0
Total	187.8	**1**56.4	-16.7

Note:* includes piece rate workers
Source: Primary survey.

Of the total labour saving, 92 per cent reduction in labour-use across medium farms was for hired workers and in the case of large farms, the entire reduction was for hired labour; in fact, the use of family labour increased. The female labour-use showed a substantial saving with the adoption of HT cotton. Of the reduction in hired labour, 30 per cent was accounted for by female workers in the medium farms, the share increasing to 43 per cent in case of large farms. Even for the family workers, around 2 man-days equivalent were saved for females in medium farm, and this number in large farms was much higher, more than 7 man-days. This indicates that the burden on female family workers can be reduced noticeably with the adoption of HT

[5] HT cotton seeds were adopted by medium and large sample farmers only, the detailed tables on labour use in Bt and HT cotton cultivation for the size categories are available with the author.

technology in cotton cultivation even amongst the well-off sections of cultivators.

The analysis of task-wise pattern of labour involvement revealed that (Table 7) picking and weeding (manual and application of chemical weedicides) were the most labour-intensive tasks in cotton cultivation. With the adoption of HT cotton, the share of total labour-use for weeding-related tasks declined to nearly 11 per cent for males and 13 per cent for females. It may be noted that the share of cotton picking in total labour days concomitantly increased with the adoption of HT cotton. The share of labour, especially female, employed for removal of crop residues/land preparation also recorded a change with the adoption of HT cotton. The share of hired labour for weeding-related activity halved from around 24 per cent in Bt cotton to 13 per cent for HT cotton. In this respect, the burden of family labour too lessened from 13 per cent to close to 10 per cent of the total labour days utilized.

The detailed task-wise analysis of man-days by categories of workers for the regions and size classes of farmers reiterated that all the categories of workers — male, female, family and hired — had recorded a reduced engagement in weeding-related activities with the adoption of HT cotton.[6] The reductions were far more pronounced for manual weeding. While the hired workers could be engaged more productively in other remunerative tasks, the labour hours saved by the family workers could be considered as opportunity income. The labour saving (more so for hired labour) possibilities offered by the HT cotton technology bodes well for strengthening the process of occupational diversification and economic transformation already visible in the regions where cotton cultivation is dominant. This is true especially for the female farm workers.

Table 7. Share of different tasks in total labour-use in Bt cotton and HT cotton cultivation, 2013
(per cent to total)

Operation	Bt cotton		HT cotton		Bt cotton		HT cotton	
	Male	Female	Male	Female	Family	Hired	Family	Hired
Tractor ploughing	4.2	0.2	3.0	0.0	2.9	2.6	2.0	2.5
Sowing	5.5	6.8	4.8	5.8	4.6	6.9	3.8	6.7
Fertilizer application	6.1	2.3	5.1	14.6	5.1	4.4	4.2	11.8
Pesticide application	5.9	1.2	5.6	2.9	4.4	3.9	4.0	6.0
Manual weeding	10.0	23.3	6.0	10.1	8.4	19.4	6.0	8.4
Chemical weeding	4.7	3.9	4.7	2.9	4.1	4.6	3.6	5.0
Irrigation	7.4	2.4	7.5	0.0	5.2	5.7	4.0	7.6
Total picking	20.6	52.9	25.6	60.7	18.1	42.7	22.8	49.4
Removal of crop residues	4.5	5.2	3.0	2.9	4.5	5.0	3.4	2.5
Maintenance of bunds, etc.	3.4	1.2	1.5	0.0	3.0	2.3	2.0	0.0
Post-harvest/Marketing	0.6	0.5	0.0	0.0	1.1	0.2	0.0	0.0
Supervision	27.2	0.0	33.1	0.0	38.7	2.3	44.3	0.0

Source: Primary survey

Analysis of Input use, Costs and Returns

Since adoption of HT cotton reduces labour requirement, especially hired labour engaged in the crucial activity of weeding, it is assumed that the cost of cultivation would be substantially lower for HT than Bt cotton. Moreover, with the absence of weeds, in all possibility the consumption of fertilizer, manure and irrigation would decline, leading to a reduction in the

[6] The detailed tables are available with the author, though not reported here.

variable cost. Attempt was also made to arrive at the total paid out costs and the imputed cost of family labour along with net returns,[7] in order to compare the cost of cultivation for the two varieties of cotton and assess the welfare gains, if any, with the adoption of HT cotton.

Table 8 indicates that the total cost of cultivation was higher for Bt cotton than HT cotton. A comparison of the cost estimates for the three districts from where HT samples were drawn, it was seen that the cost of production in an acre for HT cotton (including the imputed cost of family labour) was nearly 30 per cent lower. Considering only the paid out costs (i.e. the A2 costs), and the cost of hired labour, the saving in cost of production for HT cotton in an acre was 34 per cent. The human labour saving (mainly hired labour) concomitant to adoption of HT cotton technology reflects the possibility of a decline in labour absorption in cotton cultivation through technological change.

Table 8. Costs and returns in Bt and HT cotton, 2013

(₹/acre)

Particulars	Bt cotton *	HT cotton	Change, %
Hired labour	20560	12901	-37
Animal and machine labour	2113	1769	-16
Family labour (imputed cost)	10282	8841	-14
Labour cost	32954	23511	-29
Paid out costs (purchased inputs)	9992	6919	-31
Total cost (incl. imputed costs)	42946	30430	-29
Total cost (excl. imputed cost)	32665	21589	-34
A. **Physical yield (in quintals/acre)**	8.6	5.0	-40
Cost of production (₹/q)	3798	4152	9
Gross income	38700	23400	-40
Net income	6035	181 1	-70
B. **Normal yield assumption**			
Cost of production (₹/q)	3629	2399	-34
Gross income	40500	40500	0
Net income	7835	10070	29

Note: * Average of the three districts.
Source: Authors' calculations from primary survey data

The total cost of production in Bt cotton per quintal has been found lower by nine per cent as compared to HT cotton. This stems from the fact that the physical yield in Bt cotton in districts was observed to be 9 q/acre and was 40 per cent higher than HT cotton, which reportedly was 5 q/acre. However, we need to factor in the drought situation prevailing during the survey year that accounted for the low reported yields. The net income, was around ₹.6035/acre for Bt cotton. The HT cotton was able to cover all the paid up costs and showed a net profit of ₹.1811/acre. At least for the sample, Bt cotton out performed HT cotton with regard to all the measures. For further clarity, we considered the state's average yield in a

[7] The survey year was a drought year in Gujarat due to delayed monsoon. The Gujarat region received average rainfall (June to September) of 647 mm, a departure by 28 per cent from the normal. As a result the yield of cotton (*kharif*) hovered around 610 kg/acre, as against the average yield of 9 q/acre in 2010-1 1, a normal year. As a result, output was much lower, affecting the net income. The gross value of output per hectare was estimated by multiplying the productivity of cotton with the output price (per quintal) received by the farmers. The net income/profit was arrived at by deducting the cost of cultivation from the gross value of production.

normal year (2010-11) (9q/acre) as the reference cost structure and substituted the productivity per acre of cotton in the state in a normal year. By doing so it was observed that the net profit for HT cotton would increase by a handsome margin (nearly 30% higher than Bt cotton). It is evident that the farmer-entrepreneur can cover all the paid out costs (inputs and hired labour) and earn significantly higher profits by cultivating HT cotton.

The physical yield was reportedly lower of HT cotton than of Bt cotton, possibly indicating that the as yet illegally obtained HT seeds may not be entirely suitable for the state's agro-climatic conditions. If a larger number of cotton hybrids stacked with HT gene are used, the yields and thereby profitability of cotton would be more robust. This also underscores the fact that the benefits of transgenic crop can be fully realized only when the technology is inserted into a number of locally adapted varieties or hybrids. Further, since genetic engineering is a complementary tool and not a substitute for conventional breeding, HT trait will always have to be incorporated into the locally adjusted germplasm.

The structure of average operation-wise labour cost for Bt and HT cottons was also examined. Such an analysis is useful from the view point of knowing whether farmers would be justified in using HT cotton if significant labour cost saving is experienced in the crucial tasks associated with cotton cultivation. On an average, the share of labour cost on hired workers for weeding activity (manual) nearly halved, from 19 per cent to 8 per cent with adoption of HT cotton. On the other hand, the share of labour cost for picking increased from 44 per cent to 49 per cent with adoption of HT cotton. The removal of crop residues and land preparation accounted for around 5 per cent of all labour cost in Bt cotton. This too halved to 2.5 per cent with the adoption of HT cotton. It is quite clear that with the adoption of weedicide-resistant cotton, farmers experienced reduced burden of weeds and deployed less labour for this purpose. Noticeably, the magnitude of labour cost savings for females was higher than for male in nearly all the tasks. Large savings for females were reported in manual weeding (by 75%), removal of crop residues (69%) and even sowing (51%). One can conclude that with the outcome of average cost structure that makes allowance for the drought situation, the higher profit from HT cotton cultivation is mainly due to lower input prices, including labour cost for the sample farmers. The adoption of HT cotton in the region has led to substantial welfare gains, as manifested in enhanced net incomes.

Concluding Remarks

There is evidence to indicate that the country is witnessing a process of rural economic transformation fuelled by urban growth and increase in agricultural wages. In addition, wage employment programmes by providing rural labourers with an important source of income and creating rural infrastructure, have also altered the short- and long-run equilibria in other areas of the rural economy, such as labour, technology, and agricultural output. The existence of inter-relationship between labour scarcity, technology adoption, and growth of non-farm employment opportunities often fuelled by government programmes can result in a win-win situation for the owner-cultivators and labourers to the extent that the technologies adopted increase farm productivity and pushes the agriculture sector towards a higher growth path.

The evidence on the basis of the case study categorically indicates that there is a need for greater farm mechanization coupled with introduction of technologies that are labour saving if agricultural productivity has to be maintained and stepped up. Such an outcome would no doubt enhance agriculture-industry linkages in the production process but would also have favourable income effects giving a further boost to agriculture and industry. This is imperative given the fact that in India and in Gujarat particularly, the nature of rural economy is

being driven by urbanization, out-migration from rural areas and growth in non-primary sector activities. The human labour saving (more so for hired labour) possibilities offered by HT cotton technology bodes well for strengthening the processes of economic transformation. Further, reduced expenditure on costly inputs coupled with enhanced crop productivity and profitability are the necessary precursors for providing the much needed impetus to agro-based processing activities and ultimately in strengthening the linkages between agriculture and the rest of the economy. In addition, there is a strong possibility of welfare gains for women workforce through higher incomes and education.

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