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Inter- and Intra-sectoral Linkages and Priorities for Transforming Sugar Sector of India

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Abstract

The paper has looked into the nature and extent of linkages that exist between different sub-sectors of sugar industry in India. Specifically, it has analyzed the linkages between sugarcane cultivators and processing units (sugar mills), sugar mills and *gur* and *khandsari* units, sugar mills and by-product industry of ethanol and power generation, and sugarcane and livestock sector. The paper has observed that Indian sugar sector's priorities and linkages are oriented towards ensuring availability of sugar for the domestic market and the sugar profile of the country has been different from that of major competing countries. The degree to which sugar mills and growers are integrated is the key factor in understanding various sugarcane-marketing methods that have evolved. The most important factor influencing farm-factory relations in India is the cane marketing wherein different aspects such as harvesting, cane supply arrangements, various Marketing Acts and Orders, transportation, price fixation and cane price payments play important roles. The *gur* and *khandsari* sector although provides cushioning effect to the sugar sector during surplus years, has not assumed significance to the extent as may affect the viability of sugar mills. Molasses are used for the production of alcohol in the country and in the event of its shortage, *gur* is diverted for making country liquor. The other renewable energy sector attached with the sugar industry is that of ethanol, and there is tremendous growth potential in this sector to make E10 blending an achievable option. Technological changes to enhance the capability of sugar mills are required to harness huge power potential in cogeneration. The emphasis on sugar industry financing sugarcane research, ICTs in cane marketing, awareness about quality jaggery production, use of press mud as manure, development of feeds from sugarcane tops, intercropping of pulses and mechanization of planting and harvesting operations are the areas required for integrating and transforming the sugar sector of India.

Key words: Sugarcane, sugar, g*ur* and *khandsari*, ethanol, cogeneration, inter-sectoral linkages, sugar profile, farm-factory relations, arrears, mechanization, intercropping, sugarcane tops

JEL Classification: F1, J2, Q2, Q4

Introduction

Sugar sector has been a focal point for socio-economic development in the rural areas of India. With 5 M ha of area, sugarcane occupies about 2.57 per cent of total cropped area, contributes nearly 10 per cent to the gross value of agricultural GDP in the country (SBI, 2015), and provides livelihood to around 6 million cane growers (GoI, 2005-06). Apart from being an important cash crop, sugarcane ranks third in the list of most cultivated crops, after paddy and wheat. India is one of the largest sugarcane producers in the world (producing around 345 Mt of cane per annum) and is the second largest sugar producing country, contributing around 15 per cent to global sugar production. The turnover of sugarcane and sugar-related economic activities is in the range of ₹ 80-85

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thousand crores per annum, of which 72-75 per cent share (around ₹ 55-60 thousand crores) accrues to the sugarcane farmers of the country (GoI, 2013). At present, the country has 762 installed sugar mills of different capacity including 163 new sugar mills in various stages of completion. Most of these new mills (111) are sugar complexes, integrated with an in-built mechanism for producing cogeneration and distilleries.

Sugarcane processing network generates valuable by-products, which are used in many industries. Bagasse, molasses and filter cakes or press mud are the major by-products and spent wash, furnace ash and flue gas are the minor by-products of sugar industry. The green tops and the cane trash are the wastes associated with the raw material of the industry. A sugar factory, on an average, produces about 10.0 tonnes of raw sugar, 30.0 (range 27.0-33.0) tonnes of bagasse, 4.5 (range 4.0-5.4) tonnes of molasses, 3.5-3.9 tonnes of filter/ press mud, 0.3 tonnes of furnace ash, 1200 (range 1125-1300) litres of alcohol by molasses route, and 10,000 kWh surplus electricity from every 100 tonnes of cane crushed (Thorat, 2009). Hence, the sugar industry has established highly complex backward and forward linkages with each downstream industry or the sub-sector. This paper is an attempt to understand the nature and extent of these linkages between different sub-sectors of the sugar industry. Specifically, the paper has analyzed the growth pattern of linkages between sugar mills and sugarcane cultivators, sugar mills and unorganized sector of *gur* and *khandsari* units, sugar mills and by-products industry. The paper has also delineated the weak linkages in sugarcane cultivation with respect to nutrient management and mechanization.

Methodology

The study is based on both primary and secondary data. The primary data on the nature of linkages and interactions were compiled through a survey of 40 cane farmers in central Uttar Pradesh by interacting with them in a group meeting, individually as well as telephonically during 2011-12. Informal discussions/ telephonic conversations were also held with some officials of sugar mill to identify the weak links in the development of the sugar sector. The secondary information was compiled from various published and unpublished sources. Time series data on the labour-use and machinery-use in sugarcane cultivation was compiled from the cost of cultivation statistics (CACP, 2001-10). Data from Agricultural Census 2005-06 and Input Survey of 2005-06 were compiled to obtain information on the size of cane farms, cane-growing holdings and the extent of organic sources in cane cultivation. Information on various parameters representing the nature and extent of sugar sector were compiled from IISR website, various issues of *Indian Sugar* and other ISMA publications. Growth rates were computed by using semi-log linear equations and per cent changes were estimated for assessing linkages over a period of time.

Results and Discussion

Indian Sugar Profile and Changing Global Interactions

Historically, the second millennium saw sugar rise from being as rare, costly stuff, transported in small wooden boxes by the pound, to a large bulk commodity traded in thousands of tonnes and consumed, almost ubiquitously, by virtually everyone. The sources of sugar are now totally different. Beet sugar accounted for 70 per cent of world production in 1990; the same proportion now applies to cane sugar. On top of that, grain sweeteners now represent 13 per cent of sugar production and intense sweeteners 11 per cent. The users are not the same either. Twenty per cent sugar went into industrial consumption in 1990, and about 60 per cent at present. The users are also very different. Eighty per cent of sugar consumption was in "rich" countries in 1990, it is less than 30 per cent now.

The involvement of government has grown phenomenally, not just in regulation but also in production and trade. While production and trade of sugar were entirely in private hands 100 years ago, 22 per cent, 18 per cent and 26 per cent of production, exports and imports, respectively are in government hands now. The presence of beet and cane growers in processing, unknown 100 years ago, now accounts for about 16 per cent of world production. Like in the 2nd millennium, the changes are expected during the next 50 to 100 years also. With the growing population and the on-going changes in food habits, the demand for sugar is expected to increase, and a major part of it will come from Asian and African countries that have low consumption rates of sugar at present. The changes are also expected on the production front of sugar.

A look at the changing sugar profile of the country reveals that the sugar production in India started in the first decade of the previous century and the first sugar industry was installed in 1904. The sugar production was just 1.20 lakh tonnes during the early-1930s. It received major thrusts under different plan periods and sugar production increased from 11 lakh tonnes in 1950-51 to 10 million tonnes (Mt) in late-1980s, 18 Mt by the turn of the century and to 28.3 Mt in 2006-07. During the past decades, the Indian share in global sugar production has risen from 5 per cent to 15 per cent and in consumption has gone up from 5 per cent to 13 per cent. Country is now the second largest sugar producer in the world and despite the largest consumption base in the world, it is self-sufficient and is also able to generate exportable surpluses. The estimated compounded annual growth rate (CAGR) for domestic consumption of sugar is 3.5 per cent, which is more than the global average.

Although India achieved major gains in the global scenario, it operated at a different profile (Table 1) compared to its competing countries like Australia, Brazil and Thailand. While a major portion of sugar production in these countries is meant for export, in India, the large part of the production is utilized for domestic consumption. India's exports of sugar are limited to the surpluses left after domestic consumption. Hence, the Indian sugar sector's priorities and linkages are oriented towards ensuring the availability of sugar for the domestic market at cheaper rates. Like India, many traditionally sugar-importing countries have laid more emphasis on increasing their domestic supplies, resulting in enhanced sugar production even on less suitable lands and reduced dependence on sugar imports. The implications of these developments are manifesting in wide fluctuations in production and prices, even if small weather fluctuations exist. The analysis of the profile of the country *vis-à-vis* other competing countries is necessary as, in a liberalized era, happenings at one country level do have the impact on production, consumption and trade of other countries. India with a large consumption base for sugar has a greater impact at global level, if its sugar supplies fluctuates even by a small percentage.

Indian Sugar Production Scenario and Farm-Factory Relations

Despite being the largest consumer of sugar and the second largest producer of sugar in the world, India does not have a reasonable degree of predictability in its production and trade policy with respect to sugar. This characteristic of unpredictability in production, coupled with the controls, has not allowed the sugar sector to tap its full potential. The production of sugar in India is directly related to sugarcane production and thus, in the years of high sugarcane production, sugar produced was also higher and *vice versa*. Consequently, sugar business, more so in the globalization era, has not turned out to be a source of attraction for the farmers. There are stagnant levels of sugarcane yield (0.15% growth during 1991 to 2014).

Sugarcane cultivation in India is broadly carried out in two distinct agro-climatic regions: Sub-tropical North and the Tropical South, accounting for 56 per cent and 44 per cent of the country's cane area,

Table 1. Profile of major sugar producing countries in the world (QE year 2012-13)

Country	Production (Mt)	Consumption		Exports (Mt)	Imports (Mt)
		Total (Mt)	kg/capita		
Brazil	37.5	13.1	61.3	25.2	0.0
India	23.3	23.8	18.3	1.5	1.1
EU-15	17.1	19.4	35.4	1.7	3.7
Australia	4.2	1.2	46.1	3.3	0.0
Thailand	9.0	2.8	38.1	6.5	0.0
USA	7.2	10.2	30.9	0.2	3.2
China	12.6	14.9	10.4	0.1	1.9
Russia	4.2	5.9	39.3	0.1	1.7

Source: NFCSFL (2015), ISMA (2015), Sharma (2012)

Table 2. Sugar cultivation scenario in India over the years

Particulars	QE 1970-71	QE 1995-96	QE 2013-14	CGR (%)
Area under sugarcane (lakh ha)	24.49	37.69	49.57	0.19
Production of sugarcane (Mt)	114.88	254.75	337.69	1.47
Yield of sugarcane (t/ha)	46.74	67.18	68.2	0.15
Cane crushed (Mt)	36.79	131.54	234.26	3.19

Note: CGR refers to compound annual growth rate for the period 1991 to 2014.
Source: IISR (2015), ISMA (2015)

Table 3. Total cane holdings and average size of sugarcane farms in India

State	Holdings			Average cane area per farm (ha)			
	Total (millions)	Share (%)	Per cent to total holdings	Marginal (< 1 ha)	Small (1-2 ha)	Large (> 10 ha)	Overall
Maharashtra	1.01	16.90	8.38	0.33	0.66	2.49	0.62
Uttar Pradesh	3.03	50.60	14.00	0.34	0.81	7.40	0.72
All India	5.99	100.00	5.07	0.36	0.77	3.53	0.77

Source: Govt. of India (2005-06).

respectively. With the existing level of technologies and resources, these regions have the potential to produce around 12 Mt and 16 Mt of white sugar in the country. The area under sugarcane was only 24.49 lakh ha in QE year 1970-71 which increased to 49.57 lakh ha in 2013-14 (Table 2). Despite year-to-year fluctuations in the area under sugarcane, the average increase in every five years was around 9 per cent up to the turn of the century. However, there has been no increase in area in the new millennium, on the contrary, a decrease has occurred. The proportion of area under sugarcane to the total cropped area has remained more or less stagnant at about 2.5 per cent.

There are about 6 million cane growers having the cane farm-size of 0.77 ha on average (Table 3). Among the tropical states, Uttar Pradesh has about 3 million cane growers and the size of cane farm is also large compared to the cane farms in Maharashtra and other tropical southern states. Since the size of the cane farm in India is very small compared to major sugar producing countries, it makes the adoption of costly improved sugarcane production technology almost impossible. Consequently, the production costs in India are very high. The profit margin of farmers as percentage of gross returns has decreased over the years (Sharma, 2008). The farmers are switching from sugarcane to other crops (poplars, mentha, etc.) even in most cane-intensive state of Uttar Pradesh.

A significant point in sugarcane production is the payment of price for cane supplied to sugar mills. It has been observed that while payment for the raw material in other industries is made in advance before its processing, in sugar industry, the price is not paid in advance. It is paid after 14 days when the processed product (sugar) has been sold. Not only this, the payment of cane price is usually extended up to months and sometimes to years (Rangarajan, 2012), almost killing the interests of the farmers in cane cultivation, particularly the younger generation. As indicated in Table 4, the cane price payable but remaining as arrears on a similar cut-off date on 31 March every year were 7.2 per cent (₹1225 crores) in 2008-09 and increased every year to as high as 38.22 per cent (₹ 18648 crores) during 2013-14 sugar season. The arrears (6-8%) also remained pending even after the sugar season is over by September next year.

Delayed or non-payment price situation affects the farm-factory relations. This section also analyses the linkages and relations between cane growers and sugar mills. Sugarcane being a perishable crop, must be crushed at the earliest after harvesting as it deteriorates

Table 4. Sugarcane price payment and arrears position, 2007-2014

Sugar season	Status as on date	Cane price payable (in crore ₹)	Cane price paid (in crore ₹)	Cane price arrears (in crore ₹)	Cane price arrears as percentage to cane price payable (%)
		Status as on March 31			
2013-14	31.03.2014	48794.10	30145.98	18648.04	38.22
2012-13	31.03.2013	53436.17	40734.00	12702.17	23.77
2011-12	31.03.2012	44596.21	36018.75	8577.46	19.23
2010-11	31.03.2011	36530.88	32215.59	4315.29	11.81
2009-10	31.03.2010	32051.17	29328.61	2723.09	8.50
2008-09	31.03.2009	17002.88	15777.50	1225.37	7.21
		Status after the related sugar season is over			
2011-12	15.11. 2012	51941.82	51584.96	356.86	0.69
2010-11	15.11. 2011	45035.46	44808.15	227.31	0.50
2009-10	15.11. 2010	39301.03	39236.58	64.45	0.16
2008-09	15.11. 2009	20247.00	20224.60	22.40	0.11
	31.10. 2009	20246.56	20197.54	49.02	0.24
2006-07	15.11. 2007	29455.09	27629.33	1825.76	6.20
	30.09.2007	29389.03	26,834.38	2554.65	8.69

Note: Sugar season is from 01 October to 30 September.

Source: GoI (Government of India) *Annual Reports* (2006-14). Department of Consumers Affairs, Food and Public Distribution, New Delhi.

rapidly converting sucrose into invert sugars which are non-crystallisable. For these considerations, *inter alia*, a sugarcane grower is obliged to supply cane to a particular mill. The number of farmers supplying cane to a particular sugar mill varies from region to region and also from factory to factory.

The degree to which sugar mills and growers are integrated is the key factor in understanding various sugarcane marketing methods, which have evolved. For example, in Indonesia, there is a total integration of sugarcane growing by the mill (not ownership of land). The partial integration of sugarcane by the mill also exists. Sugarcane marketing in the South East Asia may be classified as the coordination of smallholders' cane supplies by the mill. It is also of different types such as (a) direct contract by mill representatives with individual farmers (as in Pakistan), (b) the use of mill representatives (as in Thailand), or (c) the use of farmers' associations/unions (sub-tropical India) or cooperatives (Maharashtra) as the contact point under Indian conditions (where the number of cane growers supplying cane to a factory ranges between 3 thousands and 10 thousands in the South and between 10 thousands and 40 thousands in the North).

The most important factor influencing farm-factory relations is the cane marketing under Indian conditions. The harvesting, cane supply arrangements and the policy environment generated due to various Marketing Acts and Orders, transport, sugarcane price and methods of cane price payments play important roles in defining relations and linkages. Unlike most of the other agricultural commodities, the harvesting of sugarcane is closely associated with its marketing, as the cane harvesting has to be scheduled in such a way as to ensure a dedicated supply of the fresh crop to the mill in order to obtain good sugar recovery levels. Harvesting is an operation that is generally considered as the component of production and hence, included in the cost of production. However, in case of sugarcane, it is closely linked with its marketing. Hence, in many states, the implementation of this operation has been taken over by the sugar mills or the processors, and has not been left to the growers.

The integration of farmers with sugar mills could be done through price and non-price factors or by developing effective tools to improve the farm-factory relations which mostly remain at very low ebb (litigations due to price factors). The factors leading to unhealthy farm-factory relations are lack of transparency in the age-old manual marketing transactions. The advent of ICTs and deep penetration of mobiles, telephones, computers and internet in the rural India have opened opportunities to develop an inbuilt mechanism to provide instant information to the farmers and bring in more transparency, as was the case of Sugarcane Information System (SIS) developed by Uttar Pradesh Cane Department (GoUP, 2011). This system has provided a good opportunity to the sugar mills for interacting with the farmers in an effective way, and also in developing good farm factory relations (IISR, 2012). The impact of SIS on farmers and sugar mills has been quite significant (Sharma, 2012).

Inter-sectoral Linkages

(a) Sugar Mills and Unorganized Sector of Jaggery

Sugarcane cultivation, besides sugar mills, also supports the cottage industry of *gur* (jaggery) and *khandsari* making (non-centrifugal sugar). Jaggery/*Gur* production in India at present is about 5 Mt per annum from around 52-55 Mt of cane. Besides the quantum of cane available for jaggery production, numerous other factors affect *gur* production. Studies have indicated that the jaggery/*gur* production depends on factors like sugarcane price offered by the sugar mills, time of commencing the crushing operations at sugar mills, jaggery/*gur* prices and its demand in the market, and the number of operational days of sugar mills in the crushing season. This section describes three types of linkages in respect of cane supply to sugar mills and jaggery making units, association with molasses production, and jaggery consumption.

The use of sugarcane for manufacturing of jaggery has depicted a declining trend; it decreased from 57.8 per cent in 1971 to 15.3 per cent in 2012-13. So far, the production of *gur* and *khandsari* was high in the years of surplus cane when the mills were not able to provide remunerative prices of the cane to the growers. Generally, the price paid by *khandsari/gur* units for sugarcane is lower than by the State Advisory Price/ Fair and Remunerative Price. However, jaggery units invariably make prompt payment for the sugarcane supplied, which attracts some of the sugarcane farmers. The growers in need of immediate/quick cash for their produce do tend to divert part of their crop to these units. Hence, jaggery making provides an alternative/ supplementary market to sugarcane growers. This sector helps the farming community for disposing off the produce when sugar mills delay the start of operation or discontinue the operation early in the season when price situation is not favourable to them.

Incidentally, a substantial number of jaggery units (more than 50%) are located within 20 km of sugar factories in some states like Uttar Pradesh, Karnataka and Tamil Nadu, which would mean that these units interfere with the cane supplies in the registered areas of the factories. However, the cane diversion for jaggery production is meagre and is not to the extent as may affect the viability of sugar mill operations. It is during the years of lower cane production, that the sugar mills feel the pinch and blame the jaggery making units. Of late, the competition for crushing demand of cane is between the sugar mills themselves as more number of sugar mills has been established. However, it does call for development of a sound cane development plan for sugar mill with due consideration of jaggery making units in the command area and for better farm-firm linkages.

Second important linkage influencing *gur* production is the quantum of molasses available for country liquor production. Molasses are utilized for the production of alcohol in the country. The shortage of molasses supply for liquor making is compensated by using *gur* in the process. Hence, there is a big demand and high price for *gur* which results in its higher production and higher cane diversion for *gur* making. In the 1990s, the cane diversion was more than 100 Mt for jaggery making. Table 5 highlights that *gur* production was higher during the years 1993-94, 1996-97, 1997-98 and 2008-09, when molasses production was lower compared to the previous year levels. When sugar prices in the international market were high and the country had a record production of 28.33 Mt of sugar in 2006-07, cane diversion to *gur* and *khandsari* was only 9.7 per cent. The following year too was marked by a bumper sugar output and cane diversion was less than 15 per cent. However, in the year 2008-09, the sugar output (14.5 Mt) was less by more than 10 Mt and molasses production was also

Table 5. Changing pattern of production and utilization of sugarcane for jaggery

Year	Sugarcane production (Mt)	Utilization for jaggery production (Mt)	Per cent use for jaggery	Per cent use for sugar	Sugar production (Mt)	Molasses production ('000 tonnes)	Change in molasses production*	Estimated *gur* production** (Mt)
Years of highest conversion of cane to jaggery production during past 20 years (1993-2012)								
1993-94	229.7	104.3	45.4	42.7	9.8	4228	-153/-1820*	10.4
1996-97	277.6	114.1	41.1	47.0	12.9	5936	-2349	11.4
1997-98	279.5	117.3	42.0	46.2	12.9	5607	-329/-2678*	11.7
2008-09	285.0	106.2	37.2	53.4	14.5	6542	-4771	10.6
Years of low conversion of cane to jaggery production in the recent past (2010-2012)								
2010-11	342.4	61.8	18.1	70.0	24.4	10970	2570	6.2
2011-12	361.0	60.7	16.8	71.2	26.3	11824	854	6.1
2012-13	341.2	52.0	15.3	73.4	25.1	11744	-80	5.2

Note: * refers to change in molasses production over previous one and two years, respectively. ** shows estimated *gur* production @ 10% recovery

Source: ISMA (2015); Sharma (2012)

Table 6. Trends in jaggery consumption *versus* sugar consumption

Particulars	QE 1970-71	QE 1995-96	QE2013-14	CGR(1995-2014)
Sugar production (Mt)	3.7	16.4	23.8	3.39*
Jaggery production (Mt)	4.8	5.2	5.1	-2.25*
Sugar consumption (Mt)	4.0	13.1	23.0	3.39*
Jaggery consumption(Mt)	7.4	7.4	6.8	-2.46*
Molasses production (Mt)	1.62	8.3	10.8	3.38
Per capita sugar consumption (kg/annum)	7.4	14.2	20.4	-
Per capita consumption of jaggery (kg/annum)	13.6	8.0	3.7	-

Source: ISMA (2015), IISR (2015)

less by around 4.7 Mt compared to the previous year figures. (Sharma, 2012).

The third weak linkage in this sub-sector is the decline in per capita consumption of *gur* and *khandsari* at 3.7 kg/annum in 2013-14 from 13.6 kg/annum in early-1970s (Table 6). On the contrary, there has been an increase in per capita sugar consumption, from 7.4 kg in 1970s to 18.3 kg/annum at present. Though, the proportion of *gur* and *khandsari* consumption in total sugar consumption has reduced considerably, its total quantum has not gone below a certain level and there is considerable demand for jaggery in India. The Indian jaggery is known for its quality and has much demand in the neighbouring countries too. The export of cane jaggery was of 17.84 thousand tonnes in 2013-14 worth ₹ 153.52 crores (APEDA, 2015).

Jaggery has high nutritive value as compared to sugar as it preserves all minerals and vitamins found in cane juice. It is also a very rich source of iron (11mg/100 g). Through its attractive packaging and value addition, and by making a component of mid-day meal scheme, especially in most backward districts, it could be a very nutritive food additive to fight malnutrition and iron deficiency in pregnant women and children in rural areas. This would help in creating additional demand for more production of this sweetener and to regain its past glory of higher per capita consumption in the country. Missing links for encouraging higher

Table 7. Yields of sugarcane tops (SCT) and other aerial biomass in sugarcane cultivation

Biomass	Dry matter content (%)	Relative aerial biomass (% dry matter)*	Green weight (t/ha)	Fresh weight (%)
Millable cane	32	56-62	60	71.28
Sugarcane tops	26	12.5-18.0	15	17.95
Trash	85	24-26	9	10.77
Total	-	-	84	100.00
SCT/ cane ratio (Dry matter basis)	-	20-32	-	25.18

Notes: *Estimates are based on studies carried out at Natal (from 1940-1952), Hawaii & Mauritius.
Sources: Barnes (1974); FAO (1971)

and preferred consumption of jaggery need to be properly recognized and timely addressed.

(b) Sugarcane and Livestock Sector

The sugarcane crop supports livestock sector also in a significant way by providing forage to animals through its leaves and tops. Sugarcane tops (SCT) is generally known as a major byproduct of the sugarcane cultivation/industry and is left in the field after cane harvest. SCT production varies considerably with variety, age at harvest, growing conditions and management practices. Studies (Barnes, 1974) show that SCT is produced at the rate of 5 tonnes of dry matter (DM) per hectare, or 12.5 to 18% of the total aerial biomass of cane crop. Under Indian conditions, the SCT produced per hectare is around 15 tonnes on fresh weight basis for a 60 t/ha cane crop (Table 7) or around 18 t/ha for a 70 t/ha cane crop. Such quantum is enough to provide forage for one livestock unit (LU) over a year (1 LU = 500 kg). Hence, SCT is abundantly available in intensive cane areas.

The potential of sugarcane, and its other characteristics which make it appropriate as a feed reserve for livestock, especially in the tropics, and superior to almost all other forage crops, are its perennial growth habit, increase in quantity and nutritional quality of sugarcane with harvest interval, the optimum values being at the harvest interval of between 12 and 18 months (FAO, 1974). This is in marked contrast with almost all other tropical forage crops, which deteriorate in yield and quality as the interval between successive cuts is increased. In India, there is a long practice of feeding sugarcane tops and trash to all classes of livestock during the dry season when availability of conventional forage resources is scarce.

Due to the existing inequalities in land and the preponderance of landless or marginal animal keepers, the sugarcane tops (SCT) are in great demand. On the other hand, sugarcane harvesting is a least preferred labour-intensive operation requiring about 70–100 mandays per ha for a normal sugarcane crop. So a linkage has got developed wherein the sugarcane crop is harvested by the marginal growers and sugarcane tops are taken by them for animal feeding. This type of linkage is a win-win situation for both, as it results in a lower cost of cultivation (no cash payment for harvesting) as well as green and quality fodder for animals to landless or marginal livestock owners. The employment avenues for labour such as under MGNREGS are affecting the continuation of this linkage. This linkage needs to be institutionalized appropriately for low cost cane cultivation.

(c) Sugarcane and Renewable Energy Sector

Cogeneration of Power: The production of one tonne sugar (or 10 tonnes of sugarcane crushed) provides three tonnes (recovery rate varies between 27-33 per cent) of bagasse (Thorat, 2009). This quantity of bagasse would result in the production of 1300 **kWh** of power out of which 1000 **kWh** is the surplus power. The quantity may vary depending upon the boiler configuration. In India, about 234 Mt of cane is crushed every year, on a conservative estimate it would produce around 70 Mt of bagasse and would result in the production of around 23400 **GWh** of surplus power for a period of 150 days. This is equivalent to power generation potential of around 6500 MW. The cogeneration of power by the sugar sector in India has become a major activity since 1993-94. At all-India level, about 244 sugar mills have installed capacity to co-generate around 4654 MW of surplus power, after

Table 8. Potential for cogeneration and export of power in sugar industries in India

State/UT	No. of Cogen units		Total generation (MW)		Per cent sugar mills exporting power (%)	Cogen/ 1000 TCD
	Existing	Potential	Export	Potential		
Uttar Pradesh	60	127	1286	4600	47	2.73
Maharashtra	64	201	1036	3000	30	4.42
Total	244	562	4654	12100	43	2.13

Source: ISMA (2015)

meeting the requirement for captive use. The co-generated power from the sugar sector meets about 12 per cent of the energy shortfall. The potential to co-generate power by the sugar industry at 90 per cent operational efficiencies of existing and upcoming sugar mills has been assessed at 10500 MW (GoI, 2013). A few studies have indicated still higher total power generation potential (Shukla, 2015) at 12,100 MW (Table 8) and have estimated the total exportable power potential at 9,700 MW (KPMG, 2007). The total shortfall in the availability of power has been assessed at 15,750 MW. When its full potential is achieved, the contribution of the co-generated power would work out to an appreciable figure of about 45 per cent of the energy shortfall. In Uttar Pradesh, 60 sugar mills out of 127 operating sugar mills have established cogen units. Nearly 1286 MW of electricity is being produced of which more than 80 per cent is being supplied to the UP state electricity grid. Around 6-7 per cent turnover of the sugar mills is from power sale to the state electricity grid.

Cogeneration facility has resulted in the crushing of every kind of sugarcane variety with greater ease, as varieties having more fibre percentage result in higher bagasse production. Also, the high percentage of extraneous matter in cane is not discouraging the sugar mills. The sugar mills need to modernize and establish cogen units for having more profitability as there are still 269 standalone sugar mills. However, the small sugar mills (15 sugar mills are of less than 1000 TCD) are the weak links in this direction. Technological changes (change from low-pressure boilers) could considerably enhance the capability of the industry to generate substantially more power, which could be sold to the national grid. It is also possible to preserve bagasse, mix it with other farm wastes like rice husk and crop residues, and use the same for power generation over a larger period, to overcome the problem of seasonality associated with it. Third party sale of power and sale outside the state also need to be explored to improve generation from this green and renewable source. The cane varietal development work which is mainly focused on higher sugar content in cane also needs rethinking as high fibre percentage in cane is also in good demand in sugar mills now.

Ethanol Production

The main by-product in sugar manufacturing is molasses[1], which are used extensively for manufacture of potable alcohol, and a number of alcohol-based chemicals. Almost the entire quantity of alcohol in the country is produced from sugarcane molasses (Rangarajan, 2012). Sugar mills of high capacity have set up distilleries as their subsidiary units to process the molasses produced into rectified spirit or ethanol. In 2007, Cabinet Committee on Economic Affairs put a ban on direct ethanol production from sugarcane juice to prevent direct competition with sugar. The restrictions have been reported to be lowering the benefits to farmers as well as millers, and not allowing the flexibility in production of sugar and ethanol, as well as in managing the cyclical situations in sugarcane production (Thorat, 2009).

[1] In India, ethanol production has been taking place almost entirely through the final C- grade molasses; i.e. a litre ethanol can be extracted from 0.004 tonnes of molasses; or an average yield of 240 litres alcohol is obtained per tonne of molasses (Pohit *et al.,* 2009). C-grade molasses is the last category of molasses syrup remaining after repeatedly boiling sugarcane juice of which the maximum possible crystallisable sugar has been extracted. Grade-B molasses has comparatively higher percentage of fermentable sugar left and Gade-A has the highest percentage of these categories.

Table 9. State-wise annual installed capacity of alcohol and ethanol production in sugar industries in India

State	Annual installed capacity for ethanol production (2014)		Annual installed capacity for rectified spirit production	
	No. of units	Million litres	No. of units	Million litres
Uttar Pradesh	33	699.9	56	1186
Maharashtra	63	736.5	67	715
All India	152	2186.3	296	3774

Source: www.indiansugar.com

The primary feedstock for ethanol production in India is sugarcane molasses produced in sugar mills. An extremely important aspect is that 'Ethanol' (dehydrated alcohol) from molasses is a good oxygenate and could be used as a blend with petrol for motor fuel. On the other hand, sugarcane is the best crop for giving high yield of ethanol per ha of land.

According to estimates available, it produces about 10.0–13 litres of alcohol along with 10 kg of sugar per tonne of cane crushed in sugar mills. Assuming cane yield @ 60 t/ha, the alcohol production through molasses route would be around 696 litres per ha. If there is no compulsion to produce sugar and the entire sucrose in cane (130 kg sugar) is used for fermentation, about 66 litres of extra alcohol (total 76-77 litres) will be produced per tonne of cane crushed. From total cane crushed (234 Mt), the ethanol production from cane juice would be around 17.784 million kilolitres in contrast to 2.186 million kilolitres actual alcohol production from molasses route. It has also been estimated that with the coming up of more integrated sugar complexes designed to cater 50 per cent of mixed juice, around 24 billion litres of ethanol could be produced (Shukla, 2015).

At present, there are 296 distilleries with an annual installed capacity of 3.77 million kilolitres. Out of this, 152 units are attached to sugar mills and have the installed capacity for production of about 2186 million litres of ethanol (Table 9). This is just equal to the ethanol requirement of transport sector at 10 per cent blending but half of the requirement for E20 by 2016–17.

The growth of ethanol sector began in 2003 with the announcement of government policy to start ethanol-doping programme. However, the growth in the sector has been rather slow, as the actual production of ethanol in India has not yet kept pace with the demand. The Ethanol Blended Petrol (EBP) Programme is presently being implemented in a total of 13 states with blending level of just about 2 per cent against a mandatory target of 5 per cent. There are two reasons for this slow growth. First, the base product for ethanol (alcohol) production is in demand by two other sectors, viz. liquor producers (30-37%) and chemical manufacturers (28-35%). The slow pace of ethanol doping into petrol has also caused immense problems to the ethanol producers. The domestic supply – demand scenario is quite favourable for the industry, and it provides some sort of insularity from the world sugar markets.

As per Planning Commission of India (2003) estimates, the demand for ethanol during 2016-17 by the transport sector at E5 and E10 would be 1039 million litres and 2078 million litres, respectively, against the total ethanol production of around 2186 million litres. The average size of ethanol units is small in India and specialized ethanol production plants need to be established to support bio-fuel programme of the country. State governments need to lift curb on trade of molasses (outside state sale) (Rangarajan, 2012). Depending upon availability, E5 is clearly feasible (as 600 million litres of ethanol is required) and E10 is also achievable (KPMG, 2007), but would need to be supported by ethanol production through molasses or through direct conversion from cane juice.

A facilitating regulatory environment for higher blending programmes would require necessary changes in Sugarcane Control Order and in providing flexibility to sugar mills (for those located in less advantaged regions to start with) to shift from sugar to ethanol, based on market dynamics. Out of 560 operative sugar mills, 269 are standalone units including 15 sugar mills of very low crushing capacity (less than 1000 TCD).

Table 10. Labour use in sugarcane and other competing crops in major cane growing states of India, 2001-2010

Crop	State					
	Sub-tropical			Tropical		
	Uttar Pradesh	Haryana	Maharashtra	Tamil Nadu	Karnataka	Andhra Pradesh
	Total labour-use per ha (persondays)					
Sugarcane	166.43	173.14	260.15	295.39	275.09	325.13
Wheat	60.04	37.32	-	-	-	-
Paddy	105.92	71.00	-	117.56	150.88	104.35
Groundnut	-	-	87.20	87.58	58.20	80.31
Cotton	96.21	-	104.96	148.80	87.10	103.06
	Machine labour-use as percentage of operational cost (%)					
Sugarcane	1.24	5.00	10.76	2.22	2.82	1.30

Source: CACP (2001-2010); Sharma and Prakash (2011)

Besides, 39 units are closed. These small units may be made operative as ethanol producing units to achieve the targets for E10. Achieving E20 would need a stable blending policy and support from oil companies, auto majors and sugar industry. For this, ethanol production need not be dependent solely on sugarcane and molasses but from other raw material sources such as beet, sweet sorghum, and cassava, also. A stable EBP programme would ensure sustainable benefits for the sugarcane farmers across the nation and an alternative market for the farmers.

Intra-sectoral Linkages in Sugarcane

Mechanization of Sugarcane Crop

Sugarcane is a labour-intensive crop and requires human labour for about 166 to 325 mandays per ha (Table 10) and the human labour costs constitute more than 50 per cent of operational cost (Sharma, 2008). Most of the operations are carried out manually and use of machinery is limited to only field preparation. Intercultural operation is the largest consumer of labour (69-102 mandays), besides harvesting and planting in sugarcane cultivation in India.

Table 10 also highlights that labour use per ha is far high in sugarcane compared to its competing crops. The cost on machine labour-use in the total operational cost constitutes just 1-5 per cent in major cane growing states. The harvesting of sugarcane consumes around 40 per cent of the total labour-use and accounts for more than 20 per cent of the total operational costs. To bring down the cost of production of sugarcane, the solution is mechanization of cane harvesting and planting operations (Sharma and Prakash, 2014). Small harvesters developed so far harvest 5.8 t/ha cane as against 1.2 t/ha by manual labour (Hendroko *et al.*, 1995). Large harvesters are very costly, about ₹ 1.5-2.0 crores. In view of high cost, harvesting machines were maintained and operated by the sugar factories, on experimental basis in Tamil Nadu and Karnataka. However, these are billet type harvesters while the preference is for wholecane harvesters. The farm machinery developed for sugarcane planting operations is still on custom-hiring basis and that too in a limited area. This weak linkage needs to be addressed on priority so that mechanized cane harvesting may reduce labour-use and operational cost. A strong linkage of manufacturers, custom service providers with adequate support from the government in subsidizing the costly planting equipments is needed. This aspect also has the potential for skill development of rural artisans as well as for establishing start-ups.

Press Mud and Integrated Nutrient Management

In India, the use of FYM for sugarcane crop is much less than the recommended level. As per Input Survey 2005-06, only about 42 per cent of cane area was treated with FYM and the quantity of FYM applied was also very low, 2.89 t/ ha of cane area and 6.9 t/ha of treated area (Anonymous, 2005-06). Another by-product, the press mud, contains plant nutrients and could be an important source of organic manure for

the crops. However, such an important linkage is being ignored. The valuable press mud is sold by the sugar mills to brick kilns and is not encouraged as manure for crop cultivation.

Intercropping and Increase in Area under Pulse and Sugarcane Crops

Another weak linkage in sugarcane cultivation is the intercropping. The high-value intercrops like vegetables, oilseeds and pulses are appropriate for growing as intercrops (as the fields remain virtually vacant for almost 45 days after sugarcane is planted, i.e., germination period) and can provide additional income as well as reduce risks in the long-duration crop of sugarcane. However, the intercropping in sugarcane is not encouraged by the sugar mills as most of the intercrops are considered as nutrient draining, hampering mechanization and affecting sugar and cane yield adversely. Also, most of the sugar mills being in the private sector, are not bound to carry out the government programmes of National Food Security Mission having pulse growing component in it. The intercropping also does not find favour with the farmers because of the menace of blue bulls or *Neel Gaya*. These weak linkages are quite discouraging for the farmers and need to be managed efficiently and holistically. If managed properly, the extent of sugarcane cultivation could be increased along with more area under pulse crops and the organic sources of manure will be used efficiently for increasing soil health and cane productivity.

Conclusions and Policy Implications

Though the primary product of sugarcane is sugar, it also provides raw material for *gur* and *khandsari* industry, biofuel and organic manure production. Better understanding of the nature and extent of complex backward and forward linkages existing between different sub-sectors of the sugar industry is needed for undertaking any structural reforms in the sector. The farm-factory linkages and relations must be strong for the sustainable development of the sugar sector as the degree to which the mills and growers are integrated is the key factor in understanding various sugarcane marketing methods. The emphasis on ICTs in cane marketing, awareness about quality jaggery production and consumption, use of press mud as manure, development of feeds from sugarcane tops, and the mechanization of planting and harvesting operations are the areas for integrating and transforming the sugar sector of India. The identified linkages will have to be institutionalized if sugarcane is to be made a low cultivation cost crop. Farm mechanization with the advent of cane planters and cane harvesters may initiate custom hiring business start-ups in sugarcane cultivation. The sugar industry is the direct beneficiary of sugarcane research. But, unlike in other main sugar producing countries, the cane research in India is mostly in public sector. Very meager resources (around 0.7%) under Sugarcane Development Fund (SDF) and (around 0.22%) revenue earnings of sugar mills are disbursed towards sugarcane research. Instead of playing a major role in funding sugarcane research activities and collaborating with the research organizations in a significant way, the sugar mills have also not given the requisite support to the cane development activities in their respective command areas. Hence, there is a need to evolve a strong linkage among sugar mills, R&D institutions and farmers for increasing and sustaining sugarcane production, incomes to farmers and mills, and rural entrepreneurships development. For giving an holistic impetus to all sugarcane stakeholders, the constitution of a Sugar Board may be a better alternative.

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