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Working Paper, No. 311

Provided in Cooperation with:
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Suggested Citation: Rai, Durgesh K. (2015) : Trends and economic dynamics of guar in India, Working Paper, No. 311, Indian Council for Research on International Economic Relations (ICRIER), New Delhi

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Working Paper 311

Trends and Economic Dynamics of Guar in India

Durgesh K. Rai

October 2015

INDIAN COUNCIL FOR RESEARCH ON INTERNATIONAL ECONOMIC RELATIONS

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Abstract

Developments in international markets in recent years have transformed guar from a low value crop grown on marginal land to one that can generate substantial income for processors, manufacturers, traders and farmers. India's export of guar products, particularly guar gum powder, increased rapidly from a mere US$ 84.7 million in 2001-02 to US$ 3,930 million in 2012-13, becoming the largest agricultural export in the country. However, two years later, the value of India's exports of the product plunged to US$ 1,574, owing to a unit price decline. Fluctuations in guar prices have been a source of uncertainty and confusion among stakeholders regarding the long term outlook for the product. This study examines the major aspects of demand, supply, trends in trade, traditional and emerging end-uses, competing products, cultivation and production in order to enable the stakeholders to make an assessment of the outlook for the product and its derivatives. The outlook for guar in the long term is viewed as optimistic, based mainly on the large and sustained demand for guar gum particularly in North America created by the shale revolution. The prospects have brightened further with the emergence of China as a large export destination for Indian guar products. The country has the largest technically recoverable shale gas resources in the world and it aims to substantially increase its shale production in the coming years. The demand for the product is likely to be pushed up further across the world by the expansion of the processed food industry, which is the second largest user. However, the study strikes a note of caution on account of the volatility in petroleum prices. If the recent decline in global crude prices continues, the competitiveness of shale oil and gas production may be hit and this in turn would affect guar gum demand, at least in the short run.

Key Words: *Guar production, Guar gum, International trade, Shale gas, India, US*

JEL Classification: *Q11, Q17, F14*

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Disclaimer: Opinions and recommendations in the paper are exclusively of the author and not of any other individual and institution including ICRIER.

Trends and Economic Dynamics of Guar in India[1]

Durgesh K. Rai

1. Introduction

Guar or cluster bean (Cyamopsis tetragonoloba) is native to India and has been cultivated in the country for ages. It has been used traditionally as a vegetable, cattle food and as a green manure crop in agriculture. Commercially, guar gum is the most important derivative of guar seed and is used in a variety of industries such as food processing, oil and gas, paper, textile, cosmetics, mining and explosives. India is the world's largest producer of guar, contributing about 80 per cent of global production.

The term guar has been evolved from its most common use in India as cattle-feed "*Gowahaar (Gow means cow and Ahaar means feed)*". A drought tolerant, multi-purpose legume crop, it grows easily in semi-arid regions where less hardy crops perish. The crop has capacity to bear high temperatures and dry conditions, and is adapted to arid and semi-arid climate. It takes about 14-16 weeks to grow and requires reasonably warm weather with moderate intermittent rainfall and abundant sunshine. Guar crop grows well on light texture, sandy to sandy loam soils receiving 300-500 mm rainfall per year (Singh 2014). However, it can also be successfully grown in areas receiving 500-700 mm of rain per year (NIAM 2013). The guar crop is a Kharif (summer) crop, sown after the monsoon arrives, during July-August and harvested during late October to November. Similar to other legumes, guar is an outstanding soil-building crop. Its root nodules hold nitrogen-fixing bacteria and crop residues, which when ploughed in, enhance yields of succeeding crops (Undersander et al. 1991).

The guar seed has a shelf life of more than 3 years and needs the barest maintenance and handling environment. The guar seed has three parts: the seed coat or hull, endosperm and germ. The hull constitutes 14-17 per cent of the guar seed by weight, endosperm 35-42 per cent and germ 43-47 per cent. The endosperm contains the Gallactomannan (gum) and guar gum or guar refined splits is derived from this part of the seed. Guar gum powder is obtained from processing the guar gum or guar refined splits. There are several grades of guar gum powder, which is a white to creamy coloured, free flowing odourless powder, free from extraneous matter, and there are several grades of the product. Its ability to suspend solids, bind water by hydrogen bonding, control the viscosity of aqueous solutions, and form strong tough films are the major reasons for its use in various industries. The remaining two parts, hull and germ, are high in protein and fibre. Guar gum powder is further processed to produce various derivatives according to the requirements of different end-user industries such as textile, petroleum, paper, food and pharmaceuticals.

In recent years, guar products have acquired substantial importance in India's export basket and become one of the major export items from the country, as will be explained in the next

[1] The author is grateful to Prof. Anwarul Hoda for his supervision and guidance of the research project. The author would also like to thank Prof. Ashok Gulati and Dr. Saon Ray for reviewing the paper and providing their invaluable comments. Special thanks to all the guar farmers and guar gum manufacturers/processors for their precious inputs during the field visits.

section. In 2012-13, India exported about 406,312 MT of guar products to the world valued at about US$4 billion.[2] In fact, guar products became the largest agricultural export item in 2012-13, surpassing basmati rice. These developments have opened up immense opportunities for many key stakeholders involved in the production, consumption and trade of guar products.

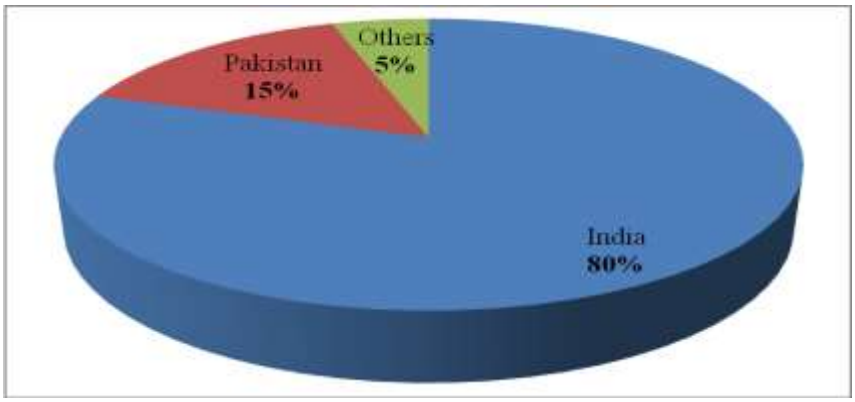
The objective of this study is to analyse the trends and economic dynamics of the guar products market in India and the world, examine its future prospects and devise strategies to advance the commercial and economic interests of Indian stakeholders. It is based on desk as well as field work involving consultations with the relevant stakeholders. The study has nine sections including the introduction. Section 2 examines global production and trade in guar products and looks at India's position in world production and trade. Section 3 analyses the price trends of guar in India and investigates the factors underlying price movements. Section 4 assesses the benefits from guar price rise to various stakeholders. Section 5 describes the uses and applications of guar. Section 6 goes into the alternatives or substitutes for guar products. Section 7 discusses the issues and challenges before the guar and related industries in India. Section 8 looks into the future prospects of the guar gum industry in India and Section 9 provides recommendations for different stakeholders.

2. Global Production and Trade of Guar Products

2.1. Global Production

Global production of guar seed is estimated at about 1.0-1.6 million tonnes annually. However, there is wide fluctuation in the production of guar depending mainly on the monsoon conditions in India, particularly in Rajasthan (Sharma and Gummagolmath 2012). As Figure 1 shows, India is the largest producer of guar seed and its derivative products with a share of about 80 per cent of world production of guar seed. Pakistan is the next largest contributor with a 15 per cent share. Other producers include US, Brazil, South Africa, Malawi, Zaire, Sudan, Australia, and China. After the recent rise in guar products prices, many countries such as Australia and China are encouraging the cultivation and production of guar, challenging India's monopoly.

Figure 1: Major producers of guar seed in world



Source: NRAA, 2014

[2] Ministry of Commerce and Industry, Government of India

2.2. Global Trade

Guar products are classified under the sub-heading 'Mucilages and thickeners derived from locust bean seeds or guar seeds' group (HS code 130232)[3] in the Harmonised System Nomenclature. This sub-heading includes guar meal, guar gum refined split, and guar gum treated and pulverised. It also covers products derived from locust beans, but international trade in these products is not assessed as being significant. We, therefore, have assumed trade under the above sub-heading to be principally in guar products.

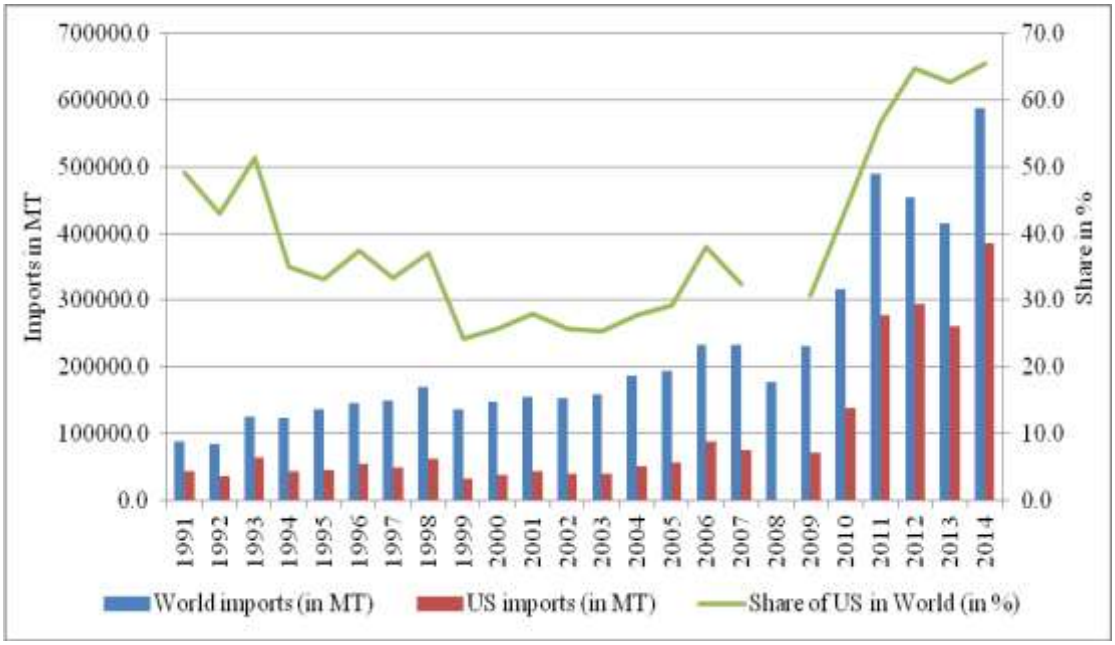
Figure 2 shows the rise in the value of world imports during the period 1991-2014 and Figure 3 reflects the trend in quantitative terms. World imports rose gradually from US$ 141 million in 1991 to US$ 751 million in 2010 but experienced a phenomenal rise thereafter, reaching US$ 4,652 million in 2012, before declining to US$ 2,666 million in 2013 and further to US$ 1,994 million in 2014. In quantitative terms, global imports increased slowly from 87,832 MT in 1991 to 317,053 MT in 2010, spurted sharply to the level of 490,063 MT in 2011 before declining to 454,377 MT in 2012 and further to 415,908 MT in 2013. Thereafter global imports bounced back, reaching the all time high of 588,229 MT in 2014.

Figure 2: Value (in US$ million) of global imports of guar products (HS 130232) and share of US

Source: UNCOMTRADE

[3] The HS 130232 also includes some non-guar products such as Kappa Carrageenan and derivatives from locust bean. However, the share of non-guar products in total trade in HS 130232 products is negligible. For example, in India, the share of non-guar products in total export of HS 130232 was less than 0.30 in 2012-13. In US, the share of non-guar products in total imports of HS 130232 from India was less than 0.1 per cent.

Figure 3: Quantity (in MT) of global imports of guar products (HS 130232) and share of US



Source: UNCOMTRADE

As would be seen from Figures 2 and 3, the US has been the largest importer of guar products for a long time and its dominance has increased further in recent years. In 2014, the US accounted for 65.5 per cent of world imports by quantity and 67 per cent by value. Other major importers of guar products include China, Germany, Canada, Japan, Australia, Russian Federation, UK, Denmark and the Netherlands.

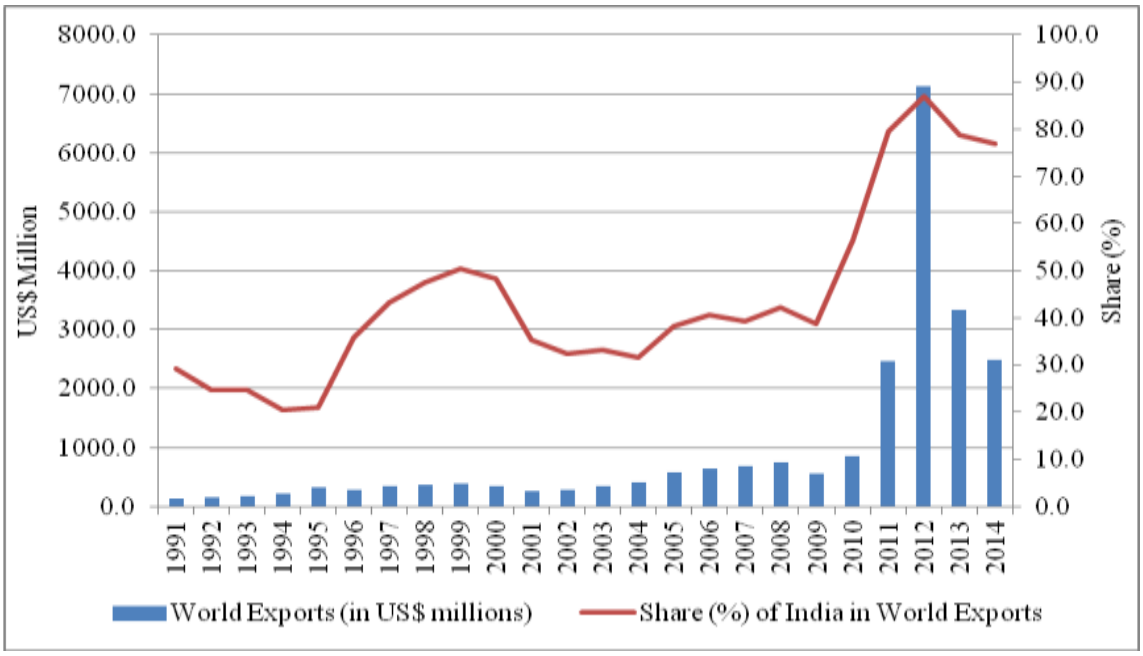
With rising living standards in Asia and South America, the consumption of guar gum is likely to increase in these regions too as demand for processed food increases.[4]

2.3. India: The Leading Supplier of Guar Products

India has always been one of the leading players in world supplies of guar products. Other major exporters of guar products include Spain, US, Pakistan and Italy. During 1991-2010, India's share of global export of guar products ranged between 20 to 56 per cent. However, there has been a substantial jump in Indian exports of guar related products in recent years. As Figure 4 shows, India's share in global exports of guar products by value reached 87 per cent in 2012 before marginally declining to 79 per cent in 2013 and to 77 per cent in 2014.

[4] http://www.nmce.com/files/study/guarseed.pdf

Figure 4: Value (US$ million) of global exports of guar products (HS 130232) and share (%) of India



Source: UNCOMTRADE

Export of guar products from India to the world market, especially to the US and Europe, began in the early 1960s (Mathur 2012). Guar products have become one of the largest agricultural export products from India during the last couple of years. In fact, guar accounted for about 18 per cent of India's total agricultural exports in 2012-13.[5] There has been a remarkable increase in both the export value and volume of guar products. As can be seen from Figure 5, the value of Indian guar product exports increased from a mere US$ 84.7 million in 2001-02 to about US$ 650 million in 2010-11. Thereafter, the export grew at a galloping pace and reached about US$ 3,930 million in 2012-13, making guar products the largest agricultural export item in that year. However, the value of exports declined later to US$ 1,574 million in 2014-15. The rise/fall in value of exports was due more to a surge/decline in unit values of exports rather than to an increase/decrease in quantity as can be seen in Table 1.

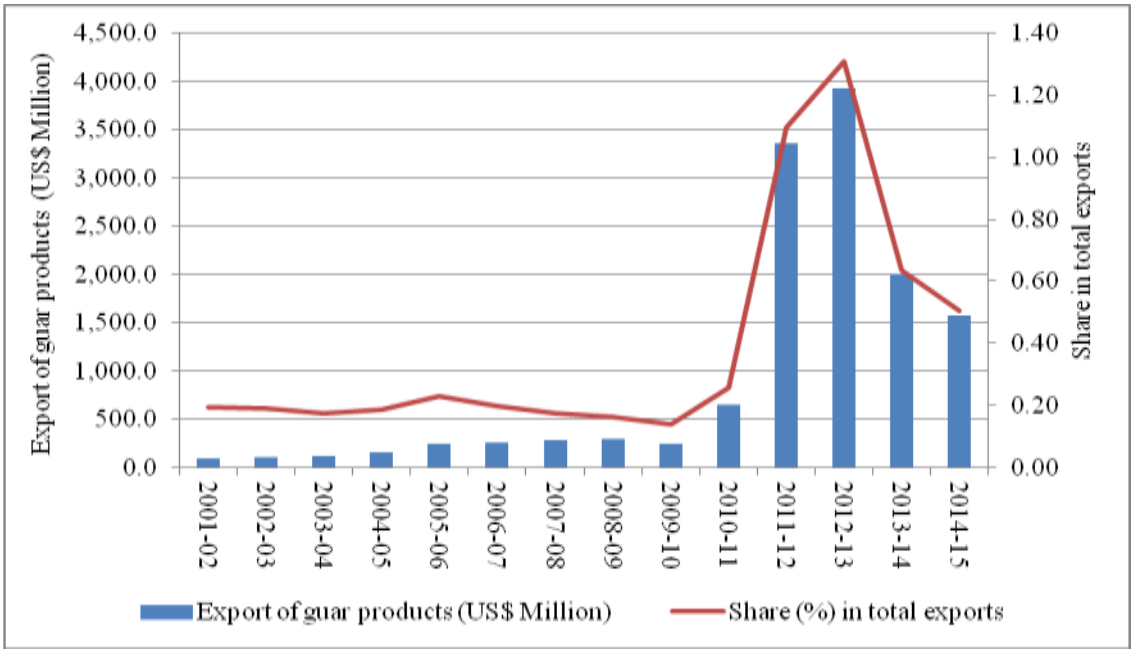
Table 1: Quantity (MT) and value (Rs. Crores) of guar products exports from India

2010-11		2011-12		2012-13		2013-14		2014-15	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
441,607.68	2,938.72	707,326.42	16,523.83	406,311.80	21,287.07	617,035.7	11,853.13	688,866.9	9,611.27

Source: Department of Commerce, Ministry of Commerce and Industry, Government of India

[5] http://www.thehindubusinessline.com/markets/commodities/guar-price-could-perk-up-on-demand-from-shale-gas-sector/article6152196.ece

Figure 5: Export of guar products from India and its share in total Indian exports



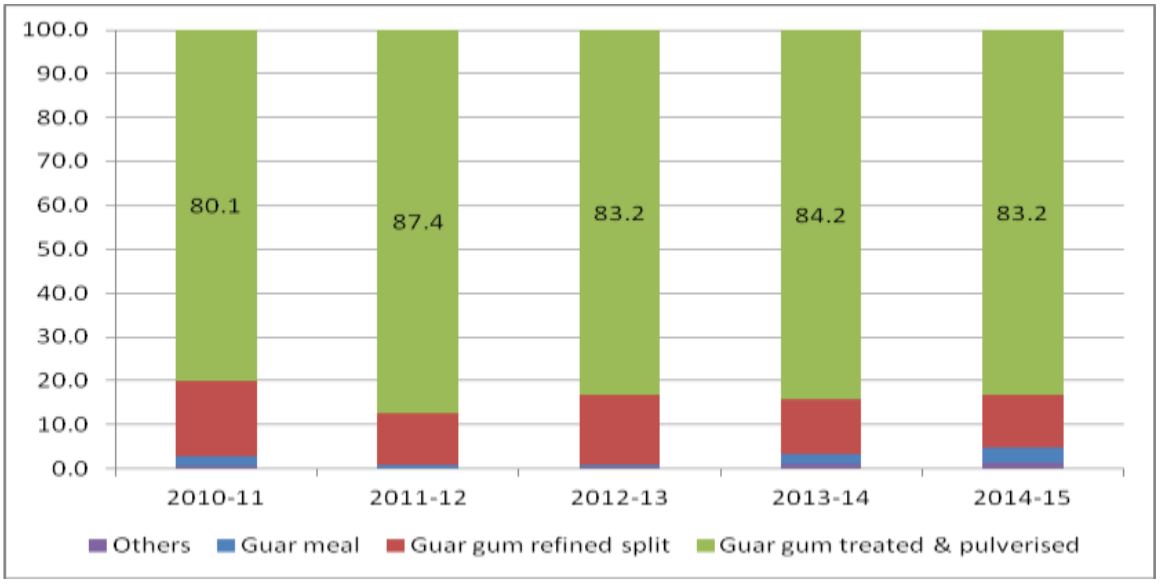
Source: Department of Commerce, Ministry of Commerce and Industry, Government of India

Guar products are exported from India to more than 100 countries. However, the US is the largest export destination. In 2014-15, about 73 per cent of Indian exports went to the US followed by China (5.4 per cent), Canada (3.2 per cent), Germany (3.1 per cent), Russia (2.8 per cent) and Italy (1.1 per cent). Although the US was always the major market for Indian guar products, there was a big spurt in US demand in the recent past raising its share from about 41 per cent in 2009-10 to 81 per cent in 2012-13. After reaching a peak, the share declined to about 73 per cent in 2014-15.[6]

Export of guar seed from India is banned and only processed and semi-processed products of guar seed are allowed to be exported.[7] Processed products of guar seed include guar gum treated and pulverised, guar gum refined split and guar meal. Processed guar is exported from India primarily as guar gum treated and pulverized (finished product) and refined splits (semi-processed product).[8] Guar gum treated and pulverized, which is also known as guar gum powder, has dominated the Indian export basket of guar products, as shown in Figure 6. During each of the last five years, the share of guar gum powder was more than 80 per cent in total guar product exports from India.

6 Export-Import Data Bank, Department of Commerce, Government of India
7 http://www.indianembassy.org.cn/commercialwing/dynamiccontent.aspx?menuid=3&submenuid=0
8 NRAA 2014

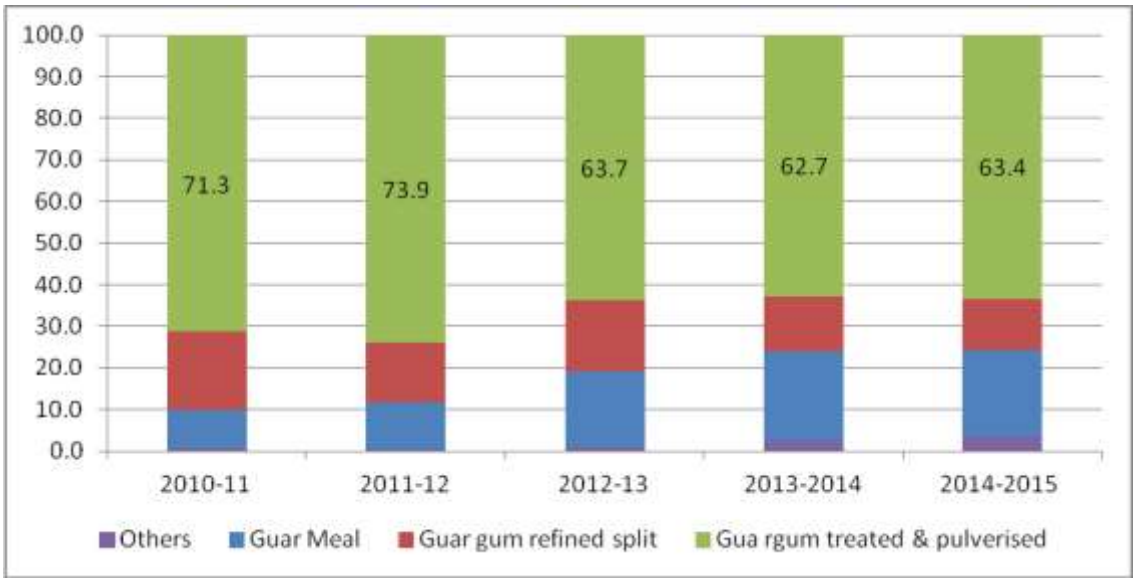
Figure 6: Composition of guar products export (value in US$ million) from India, 2010-11 to 2014-15



Source: Department of Commerce, Ministry of Commerce and Industry, Government of India

Guar gum powder is also the dominant item in terms of quantity of exports. As Figure 7 indicates, the share of guar gum powder in total guar products exported from India has remained high, in the range of 63- 71 per cent in the last five years up to 2014-15. If we look at the data for a longer period we find a significant trend of India's export moving towards more value-added products. The share of guar splits, which is a semi-finished product, has declined, both in value and volume terms, from about 34 per cent in 2000-01 to about 12 per cent in 2014-15.

Figure 7: Composition of guar products export (quantity) from India in 2010-11 to 2014-15

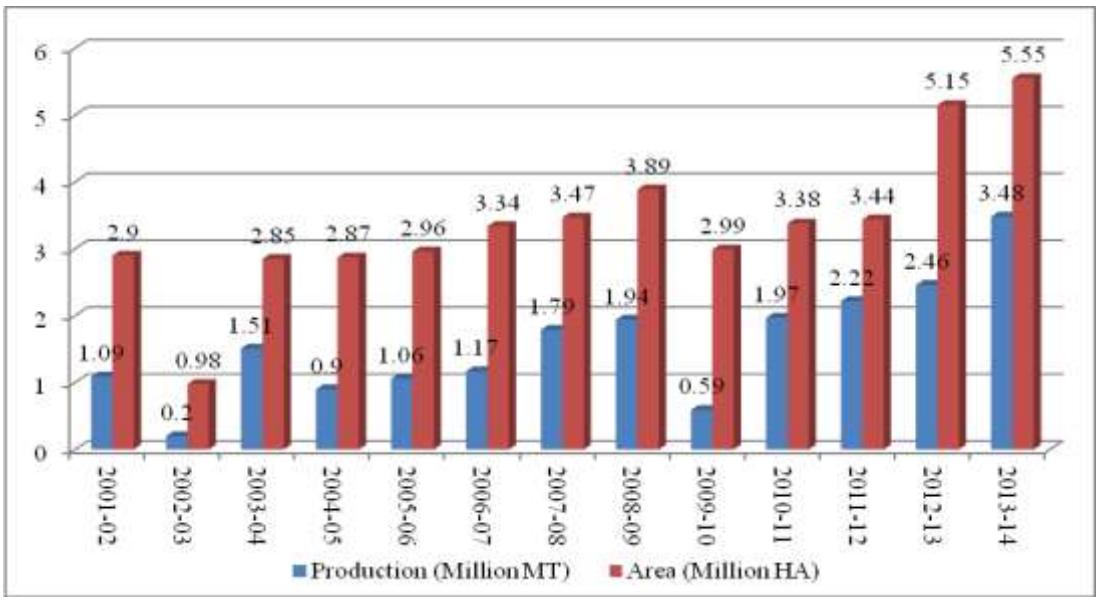


Source: Department of Commerce, Ministry of Commerce and Industry, Government of India

2.4. Production of Guar Seed in India

As noted earlier, India has been the largest producer of guar seed in the world for a long time, and during the last decade, both the production and area of cultivation have increased further. The total production of guar seed has increased substantially from about one million MT in 2001-02 to 2.46 million MT in 2013-14. As can be observed from Figure 8, although the area under cultivation has also increased, it has not been as substantial as the increase in total production, indicating productivity gains during the period. It is important to note that there are large fluctuation in both production and area of cultivation for guar in India, mainly due to variability in the amount and distribution of rainfall, especially in Rajasthan. Both production and area of cultivation plunged in 2002-03 and 2009-10, largely on account of drought conditions.

Figure 8: Production and area of cultivation for guar in India



Source: NRAA 2014, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, agriculture departments of Rajasthan, Haryana and Gujarat, and Agriwatch.

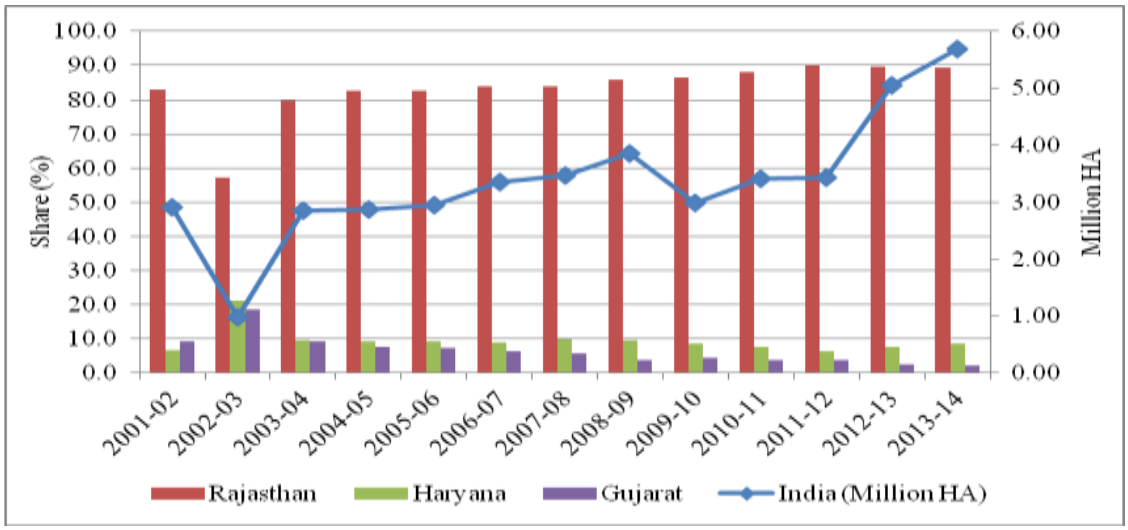
Note: All India data for 2013-14 include production from three states Rajasthan, Haryana and Gujarat. The cultivation area data for 2013-14 are just for two states Rajasthan and Haryana and the data were obtained from their agriculture departments. For Gujarat the data is taken from Agriwatch Monthly Report Oct 2014.

Guar is produced mainly in the north-western part of the country, especially in Rajasthan, Haryana and Gujarat. About 98 per cent of guar cultivation is concentrated in just these three states. As Figure 9 shows, Rajasthan is the most important guar growing state and accounts for more than 80 per cent of area under guar cultivation in the country. It is also grown in some areas of Punjab and Uttar Pradesh but these states account for a small part of the area and production. However, the big price rise in 2011-12 has motivated farmers in other states like Andhra Pradesh to cultivate the crop. Farmers in Ananthapur, Guntur, Karnool, Rangareddi, Karimnagar, Nellore, and Prakasam districts of the state have started cultivation

of guar over an area of more than 1,000 hectares.[9] Cultivation of guar is also being introduced in other states like Maharashtra, Tamil Nadu, and Karnataka. It is also being revived in traditional producer states like Uttar Pradesh and Madhya Pradesh.[10]

The price rise after 2009 has made guar an attractive alternative as compared to other crops such as 'bajri', 'moong' and cotton grown during the season. This was emphasised during interactions with guar growing farmers in Rajasthan. Many guar growing farmers have increased their area of guar cultivation and several new farmers have taken it up. The farmers were also of the opinion that price of guar seed at Rs. 45-55/Kg was reasonable and if per acre productivity stayed at about 6.0 to 7.0 quintal/acre, they would like to produce guar instead of the competing crops such as 'bajri' and 'moong' or even cotton in some regions. It was revealed during the field survey that in some areas, like Sri Ganaganagar of Rajasthan, farmers have substantially increased the cultivation of guar and reduced the cultivation of cotton over the last few years.

Figure 9: Share (%) of major states in total area (million HA) of guar cultivation in India



Source: NRAA 2014 and Departments of Agriculture of Rajasthan, Haryana and Gujarat

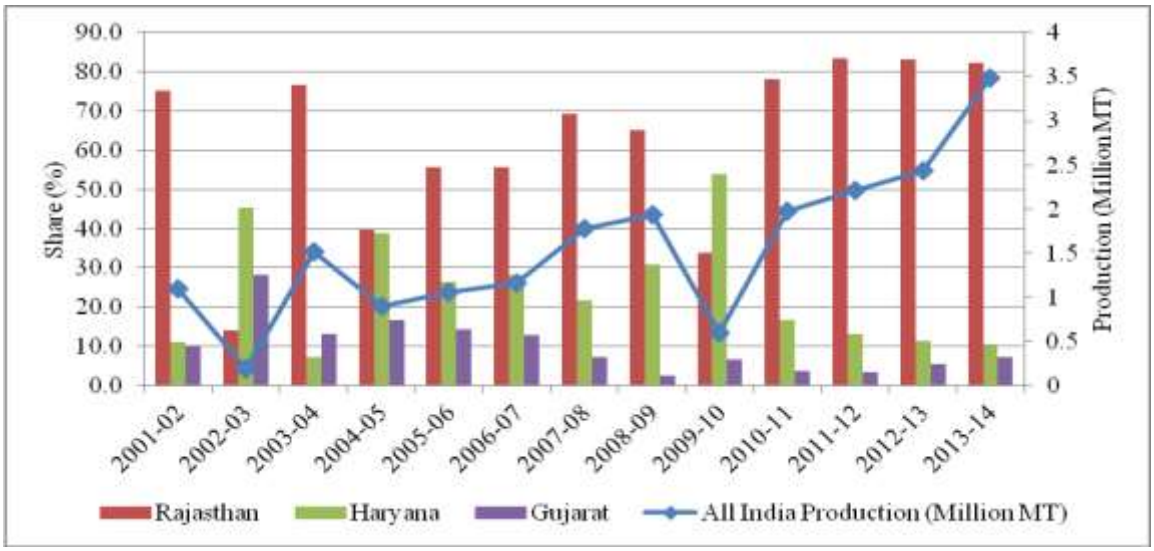
Note: All India Guar Cultivation area data for 2011-12, 2012-13 and 2013-14 include Rajasthan, Haryana and Gujarat. Due to the lack of availability of data for Gujarat for 2013-14 we have assumed the average area of cultivation of the previous five years in the state to be the area under cultivation for that year.

As Figure 10 shows, except in 2002-03, Rajasthan has been the most important guar producer state followed by Haryana and Gujarat in the country. Together, these three states account for about 98 per cent of total guar production in India. During 2001-02 to 2011-12, Rajasthan's average share in total guar seed production in the country was more than 67 per cent. However, the share of various states in the total national production has been fluctuating. Due to its greater dependence on rainfall and paucity of irrigation facilities, guar production in Rajasthan is more vulnerable to drought or drought like conditions than in Haryana where irrigation facilities are relatively better.

[9] Many companies such as AGRILOGIX in Andhra Pradesh engaged in different farming activities have started cultivation of guar on their own as well as through contract farming.

[10] NRAA 2014

Figure 10: Share (%) of major states in total production (million MT) of guar in India



Source: NRAA 2014, Departments of Agriculture of Rajasthan, Haryana and Gujarat

Note: All India production for years 2011, 2012 and 2013 include only from Rajashthan, Haryana and Gujarat; for 2013 Gujarat's data were obtained from Agriwatch Monthly Report Oct 2014.

In Rajasthan, guar cultivation is concentrated in 10 districts, namely, Bikaner, Barmer, Jaisalmer, Churu, Hanumangarh, Sri Ganganagar, Jodhpur, Nagaur, Sikar and Jhunjhunu, which account for 88 per cent of the production and 92 per cent of the area. The districts in Haryana that produce guar are Bhiwani, Sirsa, Mahendragarh and Rewari and the districts in Gujarat are Kutch, Banaskantha, Mehsana, Sabarkantha and Ahmedabad.

2.5. Evolution of the Guar Processing Industry in India

Although cultivation and production of guar has been taking place in India for centuries, the processing of guar seed to extract gum began only in the late 1950s and early 1960s (Mathur 2012). The guar seed processing technology was brought to India by two US companies – General Mills and Stein, Hall & Company.[11] This led to development of guar galactomannan[12]-based industries in India. Pakistan also became a destination for same type of industries (Beckwith 2012). With the emergence of India and Pakistan as major processing centres of guar seed into guar gum powder, the importance of US and Europe in the industry gradually declined. However, since proprietary and patent rights are still owned by US and European companies, some processing centres still exist in these economies and they import guar splits from India and other countries and process them for specific industrial uses. For example, Rhodia, a European chemical company based in Vernon, Texas, is one of the major companies that imports splits from India and Pakistan for further processing.[13]

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11 http://www.energy4me.org/hydraulicfracturing/wp-content/uploads/2013/07/Depending-on-Guar-for-Shale-Oil-and-Gas-Development.pdf

12 Galactomannans are a group of polysaccharides exclusively produced in legume plant seeds, including guar seed. Many legume seeds have galactomannans as reserve polysaccharides that provide adequate environment for germination of the seed and protects against water stress during periods of water scarcity.

13 http://www.energy4me.org/hydraulicfracturing/wp-content/uploads/2013/07/Depending-on-Guar-for-Shale-Oil-and-Gas-Development.pdf

Growth of the guar industry in India has accelerated in recent years. Mainly, there are two types of guar seed processing industries, namely, processing of guar seed to guar gum splits and guar gum splits to powder. After processing guar seed into splits, the split manufacturers either export it or sell it to the domestic guar gum processors. Guar splits is then processed into different industry-specific guar gum powder and exported or sold to domestic user industries. The split units in India have indigenous plant and machinery (Sharma and Gummagolmath 2012). Guar gum processing technology was initially transferred to India from the US. However, now it has been adopted by Indian companies and a number of improvements have also been made over the basic technology. Many of the guar gum manufacturing companies in India are ISO certified and follow good manufacturing practices. This has resulted in acceptability of guar gum produced in India across the world (Mathur 2012).

During the last few years, the number of guar based industrial units has substantially increased in India, especially in the major guar producing states of Rajasthan, Haryana and Gujarat. These industries are located mainly in Jodhpur, Sri Ganganagar, Alwar, Bikaner and Jaipur in Rajasthan, in Bhiwani and Sirsa in Haryana, and in Deesa, and Ahmedabad in Gujarat. The major trading centres for guar products in the country are also located in these states. The year 2011-12 was a watershed year for the development of guar industry in India. The demand for fast hydrated gum[14] for fracking purpose in the shale gas industry touched new heights. This resulted in a rise in the prices of guar products and led to the establishment of many new processing units, especially in Rajasthan. Currently, there are more than 600 guar gum manufacturing units in India with a processing capacity of about 7-8 lakh MT annually, of which only 4.5-5 lakh MT of capacity is utilised (NIAM 2013). The largest guar splits and powder manufacturers/processors in India are listed in Table 2, which also shows their current and projected installed capacity.

Table 2: Installed capacity of leading guar gum manufacturers in India (in MT)

S. No	Processor	Current Installed Capacity	Projected Installed Capacity
1	Vikas WSP	58,800	145,000
2	Hindustan Gums	50,000	71,000
3	Jai Bharat Gum	64,000	64,000
4	Naveen Gum & Chemicals	22,000	22,000
5	Shree Ram Gum	21,000	21,000
6	Altrafine Gum	21,000	21,000
7	Lucid Group	20,000	20,000
8	Neelkanth Polymers	19,000	19,000
9	Supreme Gums Pvt. Ltd	15,000	15,000
10	Shulaxami Industries	12,000	12,000
11	Rama industries	12,000	12,000
12	Others	335,000	378,000
Total		650,000	800,000

Source: Singh, Subodh Kumar 2013: Emerging trends in guar farming, processing and application. Paper presented at the Guar International Conference December 6-7 2013, Jaipur India. Data extracted from NRAA 2014.

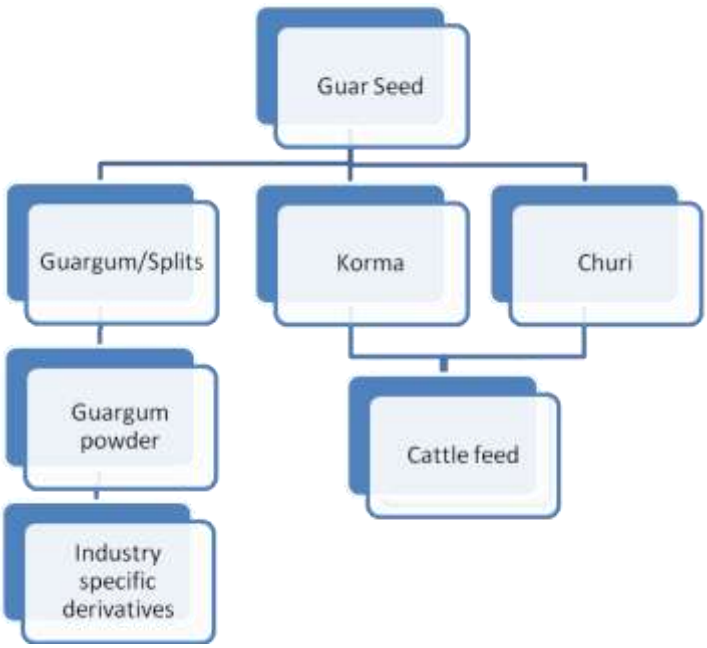
[14] Based on modification of guar gum by mechanical processes, there are three types of guar gum- (i) Normal Guar Gum (ii) Slow Hydrating Guar Gum and (iii) Fast Hydrating Guar Gum

The fast pace of increase in exports and prices of guar after 2009 has led to large capacity enhancements in the guar processing industry. The existing manufacturers/processors increased their capacity from two to ten times and many new companies entered the industry, resulting in a substantial increase in the overall guar processing capacity in the country. During consultations with stakeholders, industry representatives pointed out that the present guar processing capacity in India was in excess of even the total global demand for guar products. There is an expectation that consolidation will take place in the near future and inefficient units will exit the industry.

2.6. Structure of Guar Processing Industry in India

Figure 11 depicts the value chain of the guar processing industry in India. Guar gum powder is the most value added product and is on the top of guar processing value chain in India. It is derived from guar gum/guar gum refined splits, which is extracted from endosperm part of guar seed. The powder is used directly in some industries while others use it for further processing into industry specific derivatives. The Indian guar processing industry is mainly involved in stages two and three, i.e., in manufacturing guar gum or guar splits from guar seed or further processing guar gum powder from guar splits. Most companies are engaged in guar gum/guar gum refined split processing and some are in manufacturing of guar gum powder. There are very few companies involved in the production of industry specific derivatives. The share of the top 10 companies in the total manufacturing capacity of the industry is more than 50 per cent. There is also a huge variation in terms of the processing capacity of different companies, which varies from about 8 MT/day to 250 MT/day. Most guar gum powder processors source their raw materials, guar gum/guar split, from guar gum/split processors but some of them have their own split processing units. Some big powder manufactures have vertically integrated operations, involving the entire value chain from producing seed to processing and exporting.

Figure 11: Value chain of guar processing industry



Source: Author, based on interactions with industry

3. Trends and Dynamics in Prices of Guar in India

Given the fact that guar is produced mainly as a rain-fed crop in India, its production is subject to high year-to-year fluctuations due to variability in the amount and distribution of rainfall, particularly in the western part of the country. While the supply of guar gum is determined by the volume of production in India, the demand is influenced by the level of exports to the USA in particular, as guar products produced in the country are largely exported. The long storability of guar seeds facilitates withholding of stocks from the market in the expectation of getting a better price in future. Guar and its derivative products have witnessed large volatility in their prices over the years, particularly during 2011-12.

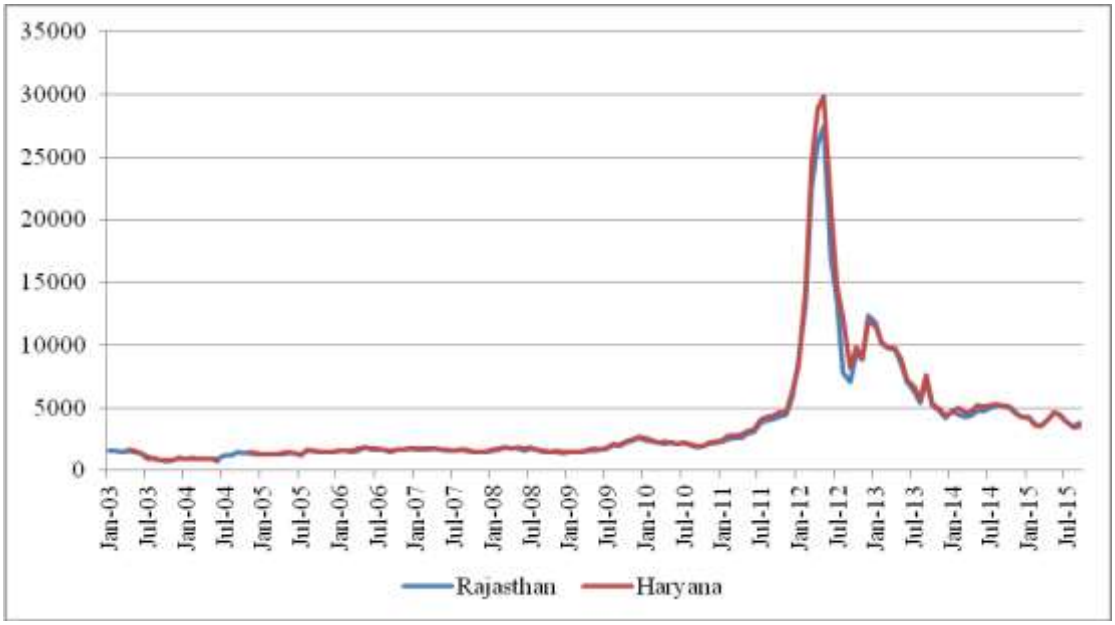
The unusual spike in guar prices during 2011-12 had an enormous impact on the overall demand and supply structures of guar products. The increase in price made the use of guar products economically unviable for many industries such as food processing and textiles, and substantially reduced demand for guar products in those industries. The shale oil and gas sector, on the other hand, became the largest user industry, accounting for about 90 per cent of total guar gum produced in India.[15] The price rise also affected the geographical diversification of Indian exports. During discussions with an exporter, it was revealed that before 2011, he used to deal with clients from 47 countries but lately he was dealing with clients from just three countries. On the supply side, the abnormal price rise led not only to substantial over capacity in the guar processing industry in the country but also to an expansion of cultivation to hitherto non-guar producing states of India. It also prompted some other countries, such as China and Australia, to encourage guar cultivation and promote the guar processing industry.

3.1. Trends in Prices

Figure 12 and 12A show the monthly trends in the whole sale prices of guar in the two major guar producing states in India. Guar prices have witnessed monthly and seasonal variations throughout the years. As far as the long term trend is concerned, during January 2003 to September 2010, guar prices increased slowly but remained within the range of Rs 1,000/quintal to Rs 2000/quintal in both Rajasthan and Haryana. However, prices increased substantially after November 2011. Prices in Rajasthan increased from about Rs 4,455/quintal in November 2011 to Rs 27,430/quintal in May 2012. In Haryana too prices increased from Rs 4,683/quintal to Rs 29,848/quintal during the same period. Prices declined sharply after May 2012 and the decline became even more pronounced after July 2012, falling to about Rs 7,100/quintal in Rajasthan and Rs 8,100/quintal in Haryana in September 2012. After a slight increase up to December 2012, there has been a continuous decline, touching a four year low at Rs 3,542/quintal in Rajasthan and Rs 3,477/quintal in Haryana in March 2015. There was some recovery in April and May but it could not be sustained in subsequent months and prices remained below Rs 4,000/quintal.

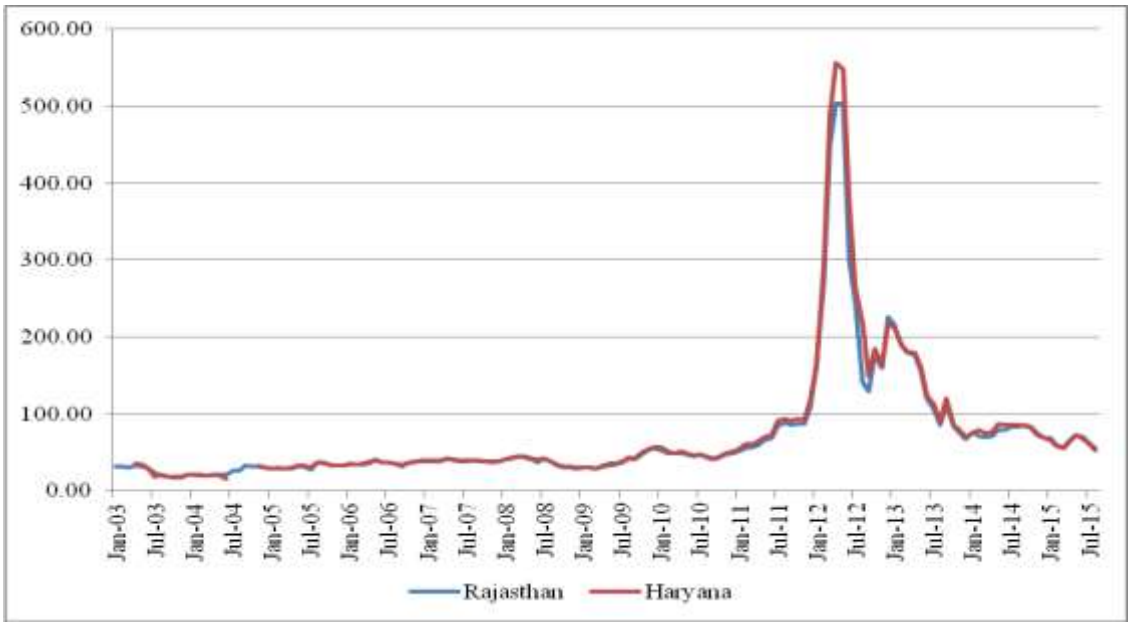
[15] NRAA 2014

Figure 12: Monthly whole sale prices (Rs/Quintal) of guar in major states (January 2003-September 2015)



Source: http://agmarkweb.dacnet.nic.in/SA_Pri_Month.aspx

Figure 12A: Monthly whole sale prices (US$/Quintal) of guar in major states (January 2003-August 2015)



Source: http://agmarkweb.dacnet.nic.in/SA_Pri_Month.aspx and exchange rate is obtained from RBI

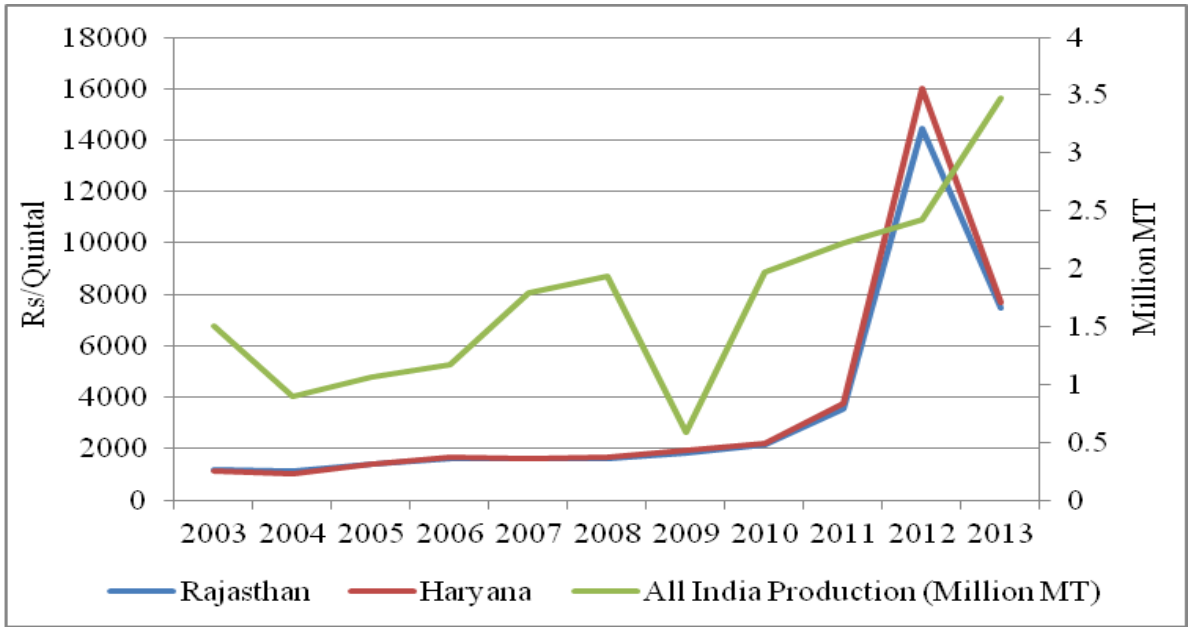
3.2. Factors Influencing Price Movements

The price of any commodity is primarily determined by the interaction of demand and supply and the behaviour of guar prices is no different. The supply and demand, in turn, are influenced by certain underlying factors. In addition, futures trade also affects the movements in prices at least in the short term.

3.2.1. Supply Side Factors

Since production of guar in India is determined mainly by rainfall during the monsoon season, any delay or inadequacy in the monsoon hampers sowing and affects the production level.[16] As mentioned earlier, the long storability of guar seeds facilitates withholding of stocks from the market in the expectation of getting a better price in future. Figure 13 shows the movement in wholesale prices of guar in the two major guar producing states and all-India production of guar seed during 2003 and 2013. The sharp fall in production in 2009 was a result of a severe drought that affected the producing regions in that year.

Figure 13: Annual wholesale prices and production of guar seed



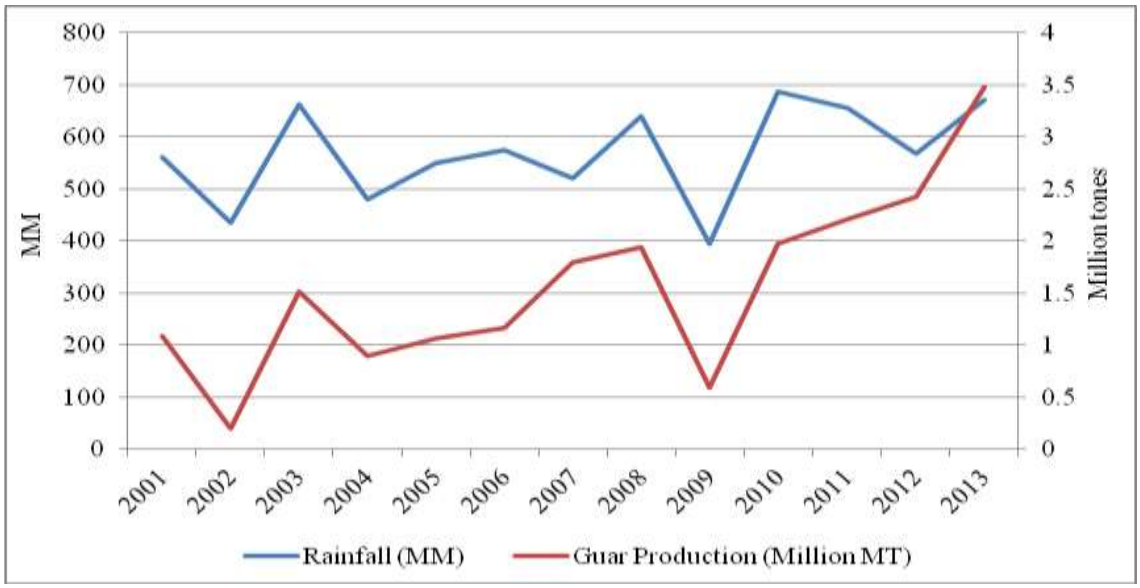
Source: NIAM, Agmarknet, Agriculture Departments of Rajasthan, Haryana & Gujarat, and Agriwatch

Note: Production data are for financial years. For 2011, 2012 and 2013 production data include three states Rajasthan, Haryana & Gujarat.

Figure 14 shows the trends in rainfall in Northwest India and all India production of guar seed during 2001-13. There seems to be a strong correlation between rainfall and production of guar seed in the country. The correlation coefficient between rainfall and production was found to be 0.82.

[16] However, in regions like Jodhpur, where average rainfall is better and farmers have other alternative crops to grow, the delay in monsoon may signal less rainfall and attract farmers to sow the guar crop.

Figure 14: Seasonal (June-September) rainfall in northwest India and production of guar seed in India



Source: India Meteorological Department; NRAA 2014; Agriculture Departments of Rajasthan, Haryana and Gujarat; and Agriwatch

Note: Production data are for financial years. Production data for the years 2011, 2012 and 2013 include three states Rajasthan, Haryana and Gujarat; for 2013 Gujarat's data were obtained from Agriwatch Monthly Report Oct 2014.

3.2.2. Demand Side Factors

More than 75-80 per cent of the total guar produced in India is exported in different forms. Until 2011, about 60 per cent of total guar gum exported from India was destined for the oil and gas industry and the rest for the food and allied industries where it was mainly used in the production of ice cream and toothpaste. However, due to sharp increase in guar prices during 2011-12, the use of guar gum in food industry was badly affected and the share of the food industry in total guar gum exports declined substantially in 2012.[17] Domestic consumption is mainly in the textile printing industry.

Table 3 shows the quantity of exports of guar products from India to the world and the US. Two aspects need to be highlighted – exports to the US have increased faster than to the world and the increase in guar exports has been particularly remarkable after 2009-10. Exports of guar products from India to the world have increased at a CAGR of 17.4 per cent and to the US at 22.2 per cent during the period 2003-04 to 2013-14. In 2011-12, India's world exports were more than three times that of 2009-10. This growth has come mainly from the US as India's exports to the US in 2011-12 were six times that of 2009-10. The share of US in India's exports hovered between 33 and 41 per cent during the period 2003-04 to 2009-10 but increased substantially thereafter, reaching more than 61 per cent in 2011-12 before coming down to 55 per cent in 2013-14. The US's share has picked up again and climbed to 58 per cent in 2014-15.

[17] http://online.wsj.com/news/articles/SB10001424127887323316804578161213056689492

Table 3: Exports (000, MT) of guar products from India to world and USA

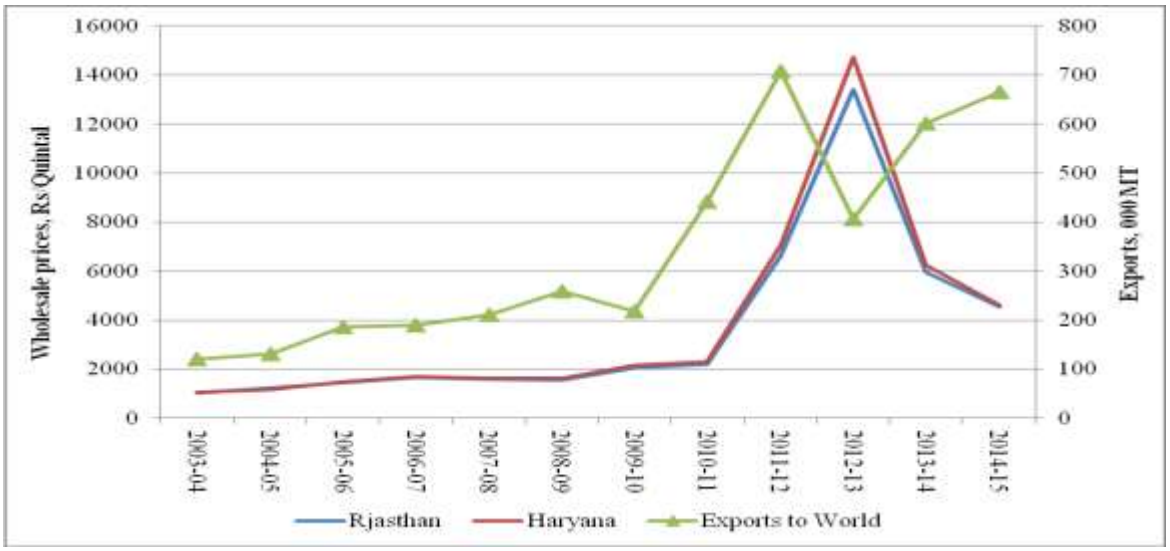
Year	World	USA	Share (%) of USA in World
2003-04	120.56	44.68	37.06
2004-05	131.30	54.05	41.17
2005-06	186.72	75.19	40.27
2006-07	189.31	66.93	35.35
2007-08	211.17	81.78	38.73
2008-09	258.54	97.15	37.58
2009-10	218.48	71.92	32.92
2010-11	441.61	215.26	48.74
2011-12	707.33	434.25	61.39
2012-13	406.3	242.60	59.7
2013-14	601.96	332.26	55.09
2014-15	665.17	384.77	57.84

Source: Department of Commerce, Ministry of Commerce and Industry, Government of India

Note: Here, non-guar products under HS 130232 are completely excluded.

As can be observed from the Figure 15, there seems to be a very strong correspondence between trends in Indian exports with a one-year lag and domestic wholesale prices of guar. As discussed earlier, since a big chunk of guar produced in India is exported to foreign countries, and a substantial proportion of that export goes to the US, exports in general and exports to the US in particular, seem to drive domestic prices. The correlation coefficient between guar exports from India with a one-year lag and wholesale prices is very high. For Rajasthan, the values were 0.89 in the case of exports to the world and 0.91 in the case of exports to US. Similarly, for Haryana, they were 0.88 and 0.90 respectively. In both cases, the correlation was found to be stronger in the case of exports to the US.

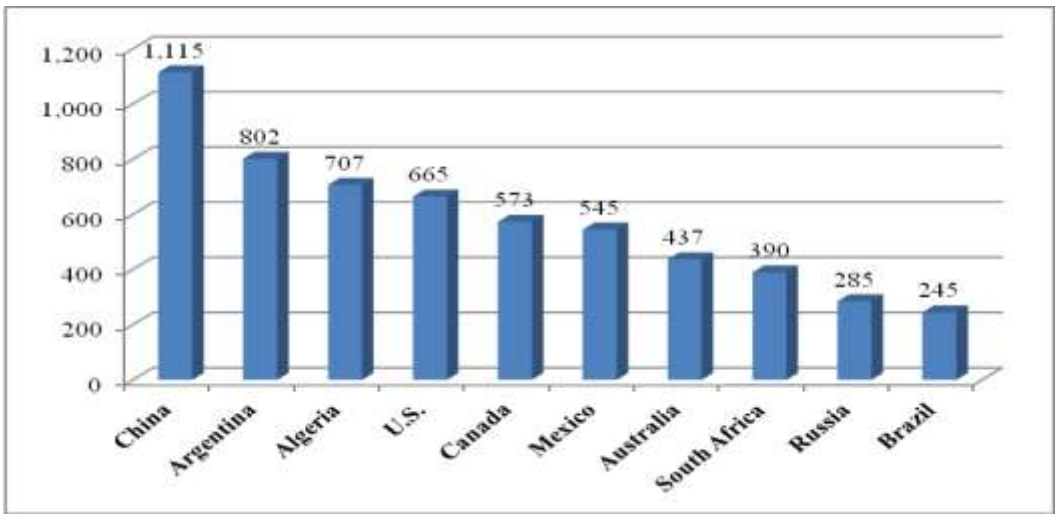
Figure 15: Guar exports (000 MT) from India and wholesale prices (Rs/Quintal) in major states



Source: Department of Commerce, Ministry of Commerce and Industry, Government of India and Agrmarknet

As mentioned earlier, China is the second largest export destination after the US for Indian guar products. Exports to China have increased at a fast pace during the past decade, rising from 13,855 MT in 2004-05 to the peak level of 59,732 MT in 2013-14, before declining to 40,168 MT in 2014-15. As Figure 16 shows, China has the largest technically recoverable shale gas resources in the world. The country aims to increase its shale gas production from the current level of 1.3 billion cubic meters to 30 billion cubic meters by 2020.[18] This is likely to have a positive impact on the demand for guar products from India in the next few years.

Figure 16: Top ten countries with technically recoverable shale gas resources (trillion cubic feet)



Source: US Energy Information Administration (EIA)

India also has an estimated 63 trillion cubic feet (tcf) of recoverable shale gas reserves. Six basins have been identified as potential areas for shale gas reserves viz., Cambay in Gujarat, Assam-Arakan in the Northeast, Gondwana in central India, Krishna-Godavari in Andhra Pradesh, Cauvery in southern India and the Indo-Gangetic plains. The Cabinet Committee on Economic Affairs has approved the proposal of the Ministry of Petroleum and Natural Gas to introduce a policy on exploration and exploitation of shale gas and oil by national oil companies (NRAA 2014). These developments in the domestic market are expected to raise the total demand for guar gum further.

3.2.2 (i) The Rise of US Shale Oil and Gas Industry and Demand for Guar Gum

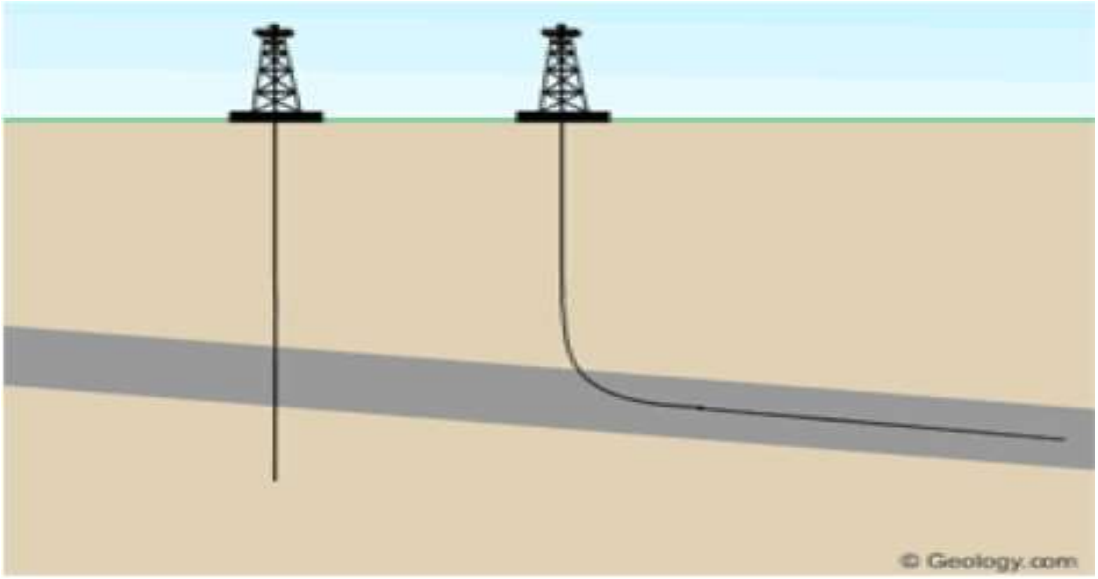
The US has witnessed a shale revolution, resulting in a very large increase in the production of shale gas and oil in recent years. This has had an enormous impact on overall economic activity in the US and in other economies such as India, which have benefited from substantial spill over effects. The existence of massive reserves of shale oil and gas in the US has been known for several decades. However, exploitation of these resources had not been economically viable until the emergence of "smart drilling technology". Smart drilling technology is a combination of hydraulic fracturing (fracking), horizontal drilling and computer-assisted underground monitoring. The hydraulic fracturing technique has been known and used for stimulating production at conventional oil and gas wells since 1947,

[18] http://www.marketwatch.com/story/chinas-shale-ambition-23-times-the-output-in-5-years-2015-02-11

while horizontal drilling technique has been in use since the year 1929. However, both techniques have been used separately. It is the combination of these two techniques that had made it possible to extract oil and gas from impermeable source rocks such as shale, which was earlier considered to be too expensive to develop (Orr 2013).

Hydraulic fracturing or fracking is a process of breaking up low permeability oil and gas rich source rocks by injecting into them fracking fluid, which is a mixture of water, sand and chemical additives. Horizontal drilling increases the surface area of the well, which is placed in the pay zone,[19] and increases the amount of oil and gas that can be recovered with one well hole. A single horizontal well can produce 25 to 30 times more oil or gas on average than a conventional well (Orr 2013). Figure 17 gives a comparative picture of vertical and horizontal drilling techniques.

Figure 17: Comparison between vertical and horizontal drillings



Source: Gelogy.com

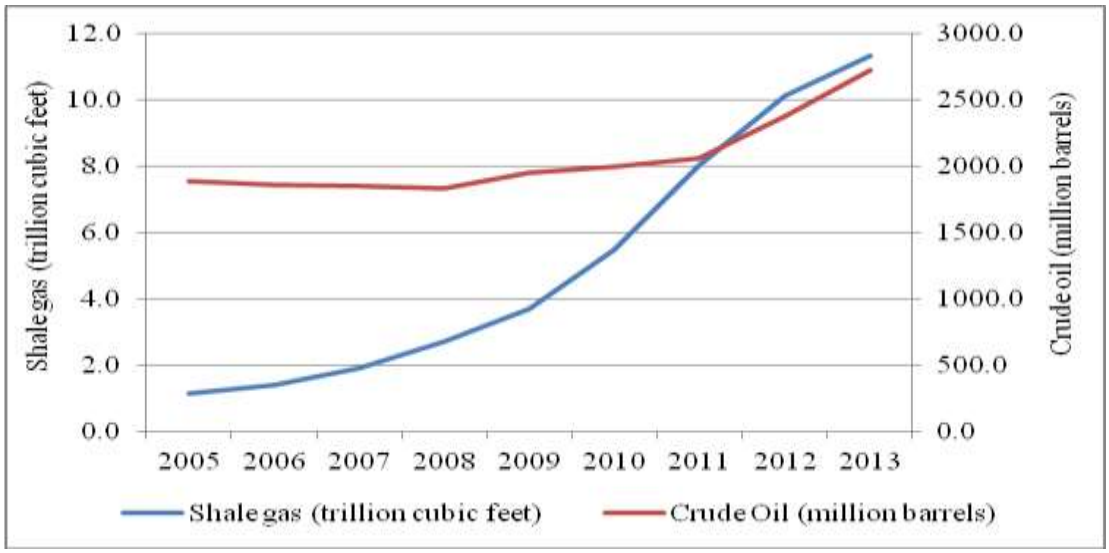
Guar gum is applied in order to thicken the fracking fluid so that it can carry the graded sand into the fractured source rocks. According to estimates, the average amount of guar gum required to hydraulically fracture one well could be as much as 20,000 lb or 90 quintals (Beckwith 2012).

As Figure 18 depicts, although the production of both crude oil and shale gas has increased during the period 2005-13, the growth in shale gas production has been truly remarkable. Production of shale gas has increased from 1.14 trillion cubic feet in 2005 to 11.34 trillion cubic feet in 2013. Although the increase in crude oil production from shale is believed to be not as high as gas production, the level of total crude oil production achieved in 2013 was the highest in the last 20 years. This has been possible only through the exploration of shale sources. The shale revolution has made US the largest producer of natural gas and brought US oil production to a 20-year high. Increase in oil production has resulted in a significant decline in the share of oil imports in total US consumption from about 70 per cent in 2009 to 37 per cent in February 2013. With these developments, according to International Energy

[19] Pay-zone is the rock layer that contains oil or gas. It is also known as target formation.

Agency, the US is projected to surpass Saudi Arabia and become the largest oil producer in the world by 2017. Further, North America is projected to become energy-independent by 2020 (Orr 2013).

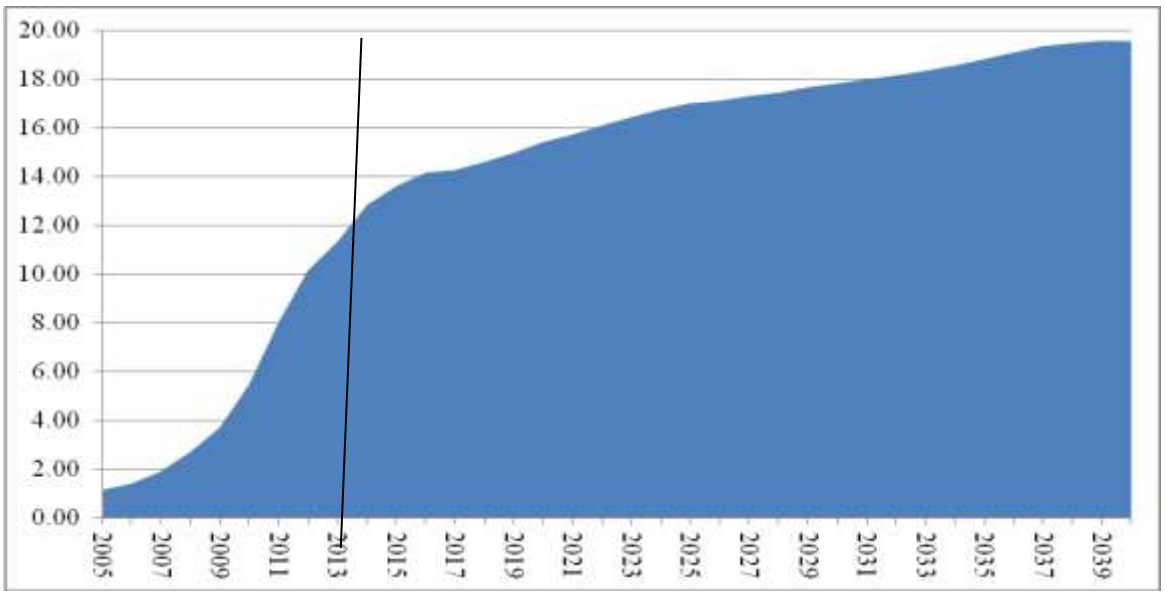
Figure18: Annual production of shale gas and crude oil in the US



Source: EIA

According to the Annual Energy Outlook (AEO) 2015, published by EIA, the production of shale gas was at its peak in 2013 and likely to further increase in 2014 and later. Although the production of shale gas is projected to increase over the next two decades before turning negative in 2040, the pace of annual growth in production is likely to witness a substantial decline after 2014. Figure 19 shows the actual and projected production of shale gas in the US until the year 2040.

Figure 19: Actual (until 2013) and projected (2014-40) shale gas production (trillion cubic feet) in the US



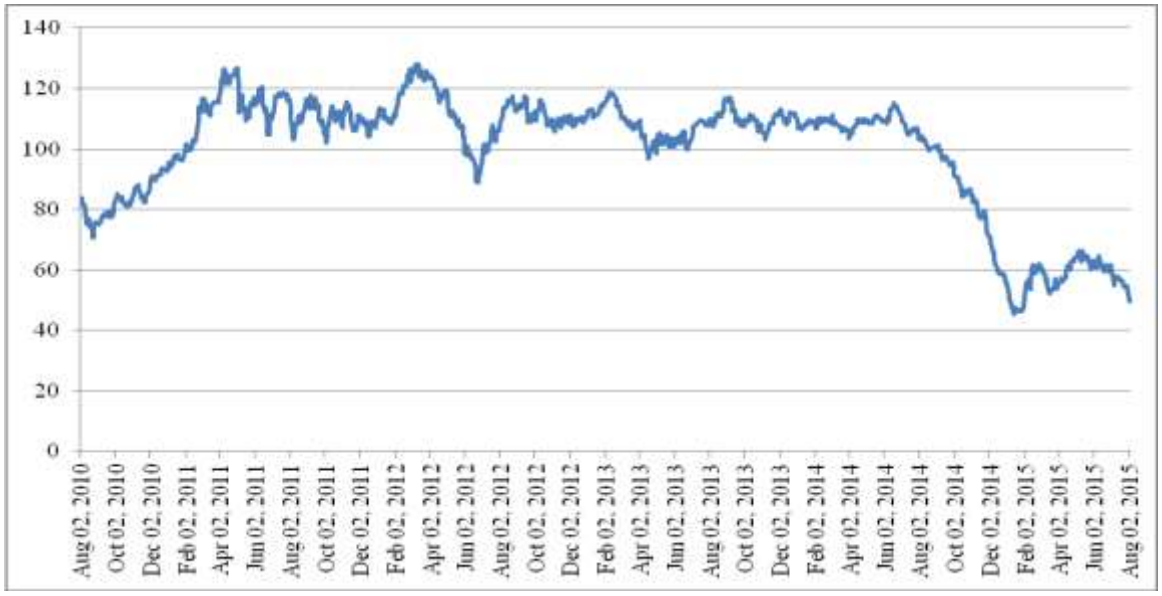
Source: AEO 2015, EIA

Note: Figure based on actual data till 2013 and projected data afterwards

Though the projected increase in the production of shale gas in the US is likely to sustain the demand for guar gum from India in the long run, the expected decline in the pace of growth of production, compared to that of last five years, will moderate the rate of growth in demand.

Further, the growth of US shale oil and gas industry has been heavily linked to the movement and the level of global crude oil prices. However, as Figure 20 shows there has been a substantial decline in global crude oil prices during last one year. International crude oil prices, which hovered in the range of $100 - $120 per barrel in the last 4-5 years, experienced a sustained decline beginning in August, 2014, and fell to the level of about $ 50 per barrel one year later.

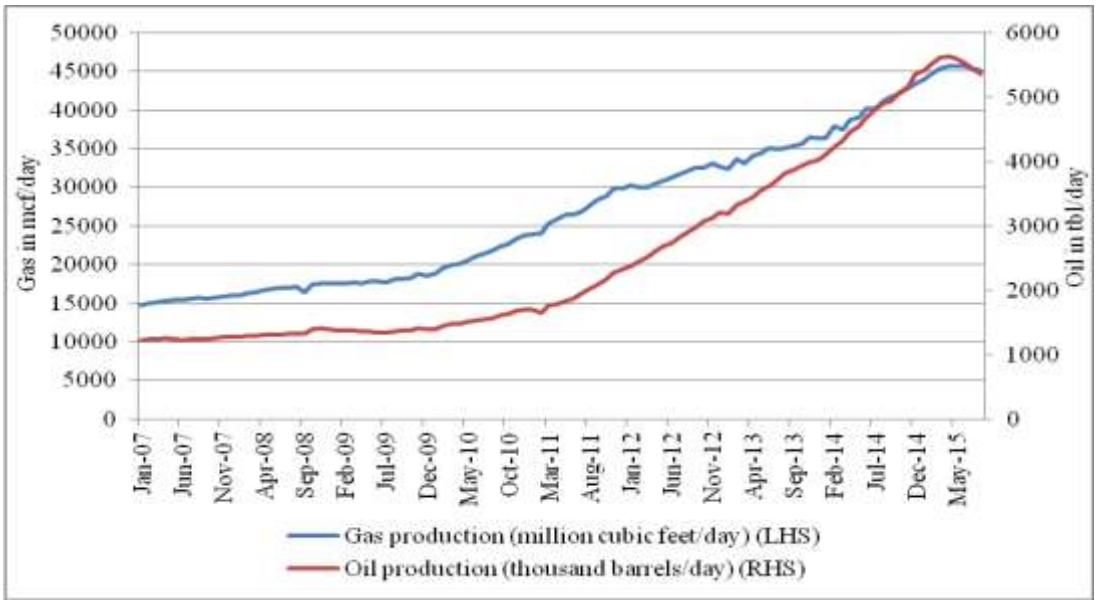
Figure 20: Europe brent spot price FOB (dollars per barrel), January 3, 2011 to July 20, 2015



Source: EIA

The US shale oil and gas industry showed surprising resilience in the face of the precipitous decline in crude oil prices and in fact the per day production of both oil and gas continued to rise until March 2015. However, the impact of sluggish crude oil price has begun to show thereafter. Most of the major shale oil and gas producing regions of US have been showing some degree of deceleration in their per day production in recent months. It is very likely that if the sluggishness in international crude oil prices continues for a prolonged period its negative impact would get transmitted to the demand for guar gum from India. Figure 21 shows that the total per day production of gas and oil from seven major shale regions (Permian, Bakken, Niobrara, Marcellus, Eagle Ford, Utica, Haynesville) of the US has declined in recent months. According to EIA's Drilling Productivity Report (DPR) of August 2015, the natural gas production across all major shale regions of US is projected to decline for the first time in September 2015 compared to September last year.

Figure 21: Production of gas and oil from major shale regions of US



Source: EIA

3.2.3. Futures Trading and Rise in Guar Prices

Apart from demand and supply factors, futures trade seems to have also played a key role in driving guar prices in India, particularly during 2011-12. Futures trade in guar seed in India began in April 2004 at NCDEX for price discovery and price risk management. Since then, guar seed and guar splits are traded at many trading centres including at NCDEX, MCX, NMCE and Bikaner Commodity Exchange. However, NCDEX is the main trading centre for guar products in the country.

Futures trading offer a hedging platform to all the key players such as farmers, manufacturers, exporters and traders in the value chain. However, the benefits from futures trade in guar seed and guar splits to various stakeholders in India have been a subject of debate and discussion, especially during 2011-12. During consultations with stakeholders, many farmers and industry representatives expressed the view that futures trading in guar products might have contributed to the surge in prices and aggravated price uncertainty, particularly during times of pressure on demand and/or supply.

While the strong demand from the US shale oil and gas industry, the fear of drought in India, and the anxiety of US buyers on future availability, which led them to hold large stocks, played a critical role in pushing up the prices of guar products to unprecedented levels during 2011-12, the futures markets also seems to have contributed to the price rise. During the period November 2011 to March 2012, the prices of guar gum surged from about Rs 11,000/quintal to Rs 98,000/quintal, an increase of almost 900 per cent, in the futures markets (NRAA 2014). During the same period the wholesale prices of guar seed increased from Rs 4,455/quintal to Rs 22,600/quintal in Rajasthan and from Rs 4,683/quintal to Rs 24,528/quintal in Haryana (Agmarknet 2015).

The Forward Markets Commission (FMC) found some irregularities in the futures market, penalized some members and suggested a number of regulatory measures to contain price

volatility. These measures, however, failed to quell price volatility and compelled FMC to suspend futures trading in guar products on March 27, 2012. However, high international demand and sustained buying, particularly by US buyers, pushed up the price further in the spot market despite the ban on futures trading and the prices continued to rise. The trend changed after May, 2012 and the decline became sharper after July, 2012. One of the main factors that triggered the decline was the large inventory built by the US buyers. The futures contract was resumed on May 14, 2013, at NCDEX and on August 5, 2013, by National Multi-Commodity Exchange Of India Limited after a gap of about 15 months (NRAA 2014).

4. Benefits of Guar Price Rise to the Stakeholders

As mentioned earlier, India's exports of guar products increased impressively from a mere US$132 million in 2000-01 to about US$ 4 billion in 2012-13. Although after hitting the peak they declined to about US$ 2 billion in 2013-14 and further to US$ 1.6 billion in 2014-15, they have still remained far higher than the historical level. The rise in exports has led to a significant surge in the price of guar products, and generated benefits for stakeholders including farmers, industry, and traders. It has created employment opportunities in the sector and increased the foreign exchange reserve of the country as well.

Until recently, guar was regarded as a poor man's crop grown largely by small and marginal farmers. However, the export boom and the substantial price rise of the past five years has converted it into a commercial crop and motivated big farmers in the traditional growing states as well as in new ones to grow the crop. Contract farming has also been started in many areas with the promise of farmers getting assured returns. There is anecdotal evidence to show that robust return from guar has changed the lifestyles of farmers in Rajasthan and Haryana.[20] A report in the journal Down to Earth describes the change in living standards of farmers in Goduwali Dhani village in Sri Ganganagar district of Rajasthan as follows:

"Kaccha walls and roofs are being cemented, and marbles [sic] have been brought in for flooring. There are new tractors in the fields and SUVs are increasing on the roads. Resident Rama Karan Charan is planning to buy his first car while Om Prakash is eyeing investment in real estate in Jaipur. Some 500 km away, Kanchan Singh in Jodhpur district is breathing a sigh of relief. He has cleared all his long pending dues. Farmers across Rajasthan have similar joys to share. Ask them the reason, they say "Guar ki kamaal" (Guar's gift)".[21]

Guar seems to offer more benefits to farmers than other crops that can be grown in the geo-climatic situation of the arid and semi-arid regions of several states. In addition to offering better income to farmers through sale of the produce, being a leguminous crop, guar fixes nitrogen in the soil and improves its fertility. If wheat is grown subsequently on the same land, productivity is likely to increase by 30 per cent.[22]

The rise in export demand for guar products has led to the expansion of guar processing industry in India and many guar processing industrial units have come up in recent years. Fresh investment has been infused in the industry, by existing processors as well as by new

[20] http://timesofindia.indiatimes.com/business/india-business/Humble-guar-gum-is-Indias-top-farm-export/articleshow/18885452.cms
[21] http://www.downtoearth.org.in/content/guar-mine
[22] Ibid

entrants. Prior to 2005-06, only 50-60 units were engaged in guar processing in Rajasthan. Soaring demand for fast hydrated gum resulted in a price rise and as many as 500 processing units were quickly established in Rajasthan alone.[23]

Expansion of the guar manufacturing industry has increased employment and generated substantial spill over economic activities in several districts of guar producing states in India, especially in Rajasthan and Haryana.

5. Applications/Uses of Guar Products

As mentioned earlier, guar has been traditionally used as a vegetable, cattle food and as a green manure crop in agriculture. However, with advances in R&D and discovery of its properties, the use of guar products has expanded to a variety of industries. According to some industry sources, guar gum has more than 1,200 uses in different industries. Guar meal, which is a by-product after extraction of guar gum from guar seed, is a rich source of protein and is used as animal feed. Guar meal is purchased by animal food manufacturers and sold to livestock farmers and dairy farms.

The major non-traditional and traditional uses of guar and its derivative products are discussed below.

5.1. Uses in Oil and Gas Industry

The oil and gas industry, especially the shale gas industry, has emerged as the biggest user of guar gum in recent years, requiring the product in large quantities. Industrial grade guar gum powder/derivatives are applied in oil well fracturing, oil well stimulation, mud drilling and for industrial applications and preparations as a thickener, stabiliser and suspending agent.

Guar gum plays a key role in the extraction process of shale oil and gas. The extraction of shale oil and gas from shale rocks is done through a hydraulic fracturing or "fracking" process. This process involves infusing a fracturing or fracking fluid, which is a mixture of water (90 per cent), sand (9.5 per cent) and chemical additives (0.49 per cent), at high pressure, to create channels in rock formations. This allows the oil or gas to move into larger pools, from which they can be taken out. The fluid carries with it a suspension of a proppant, basically sand, which is forced into the rock to offer support and stability to the channels. This is accomplished most efficiently if the sand is evenly suspended into the fluid. In order to enhance the viscosity a soluble gel is added to the fluid. Guar gum is the most efficient soluble gel currently available, requiring the least quantity to achieve a given level of viscosity.[24] According to Mr. Mickey Callanan, PfP Technology, Houston, Texas USA, guar is a perfect material for hydraulic fracturing.[25]

Gaur gum and many of its derivatives such as hydroxypropyl gum and carboxymethyl gum are being used as additives for aqueous and water/methanol based fracturing fluids. They work as agents for suspensions, water loss control, viscosity control, friction reduction or

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[23] NIAM, http://ccsniam.gov.in/GUAR_Booklet_03122013.pdf

[24] http://www.business-standard.com/article/opinion/subir-gokarn-the-guar-gum-example-113102000644_1.html

[25] Trostle and Norman 2013

mobility control. Guar gum derivatives in aqueous fluids are applied in fracturing shallow wells and shale rocks to extract oil and gas from the ground which has been trapped in shale rock formations. In these applications, guar gum's cross-linking properties are used to boost viscosity and reduce fluid loss and friction while creating fissures in rocks and soil. These derivatives of guar gum are specifically designed for different rock formations and soil matrices to frack them for exploration of oil and gas and also to enhance the flow of these petroleum products. Guar gum derivatives are widely used in these applications because guar gum contains cross-linking properties while creating fissures in the rock or soil matrix. The technology used in this process is very complex and is proprietary knowledge.

Globally, oil drilling and mining is the major consumer industry of guar gum followed by food industry, as Table 4 shows.

Table 4: Application-wise consumption of guar products in world

Type of Application	Target Industries	Global Consumption
Food grade	Bakeries (Bread), Dairy (Ice cream, Sherbets, Cheese etc.), Dressing (Sauces, Ketchup's), Beverages (Chocolate drinks) & Pet Food (Thickener)	25-30%
Pharmacy grade	Cosmetics & medicines (as binder and thickener) Slimming, (Reducing weight & laxative)	05-10%
Industrial grade	Oil drilling (as a well stimulant and fraction reducer), Mining (increased yield, filter aid), Explosives (Gelling agent), Coal Mining (fraction reducer, binding)	60-65%
Other	Textile printing (Thickening agent for dyes), Paper (increase strength and decrease porosity), Tobacco (binding and Strengthening) & Photography (Gelling and Hardening)	5-10%

Source: NIAM

5.2. Uses in Other Industries

5.2.1. Food Industry

Guar Gum is one of the most cost effective and functional ingredients available for processing a variety of food products. One of the most important components of food is water and guar gum is used to modify the behaviour of water. Guar gum acts as a thickener, stabiliser, and suspending agent in various food items. The use of guar gum in food industry was severely impacted by the unusual rise and instability in guar prices in recent years, especially during 2011-12 and 2012-13, but the industry remains the second largest user after oil & gas industry. The price volatility compelled the industry to explore and shift to alternatives of guar gum. Now that the price of guar gum is on a lower trajectory there might be a revival of demand from the food industry. Even otherwise, it is expected that the increasing global trend towards organic or natural food will cause the demand for guar

products to increase in the food industry over medium to long term.[26] The uses of guar gum in food industry are described below.

(i) *In baked food*, guar gum extends shelf life due to greater water absorption in cakes. In bread, it is used for softness and to increase the shelf life.

(ii) *In salad dressing*, guar gum is used as thickener due to its cold water dispersibility, its compatibility with highly acidic emulsions and low cost in comparison to other viscosity materials.

(iii) *In dairy products*, guar gum is used as a binder of water and a stabiliser. It is applied in the production of ice-creams, sherbets, cheese, liquid milk products, etc. Frozen food is effectively stabilised by guar gum. In frozen food products, guar gum also reduces crystal formation. Its hydration and water binding properties work as ice cream stabiliser, especially for use in high temperature and short time (HTST) processes.

(iv) *In meat and pet food products*, guar gum is used as a lubricant and binder for various meat products. It allows storage with less loss of weight and can lower the can-filling time. Guar gum increases viscosity while cooking in a kettle so that there is less splashing on the floor and canning operation can be carried out at full speed.

(v) *In the beverage industry*, guar gum is used as a thickening or viscosity control agent at a level of 0.25 to 0.75 per cent of the total weight of the product. Sugar-free dietetic beverages require inclusion of a gum to improve body and mouth feel. Guar gum is useful because of its resistance to breakdown under low pH conditions. Besides, since guar gum is soluble in cold water, it is easy to apply in most beverage processing plants.[27]

5.2.2. Paper Industry

The paper manufacturing industry is one of the major users of guar gum. Guar gum is added to the pulp suspension just before the paper sheet is produced. The pulping process is designed to remove lignin and generate a fibrous pulp. This process also removes a large part of the hemicelluloses that is generally present in wood. It adds significantly to the hydration property of the pulp and the strength of the paper created from the pulp. Galactomannans and cationic guar gum replace or supplement the natural hemicelluloses in the paper binding.[28] Guar gum provides a denser surface to the paper used for writing and printing. It improves the writing properties and increases the bonding strength and hardness of the paper.[29]

5.2.3. Textile Industry

Guar derivatives, such as depolymerised and carboxymethyl, are extensively used in textile printing. These modified derivatives provide high colour yield, reduce bleeding effect,

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[26] http://www.altrafine.com/blog/category/guar-gum-powder/
[27] http://www.shplindia.com/mcp/download/Guar%20Gum.pdf
[28] Ibid
[29] http://www.guarglobal.com/opportunity/guar-global-markets

increase sharpness and effective penetration of dye. In addition, it is also used as a sizing agent.[30]

5.2.4. Mining and Mineral Industry

In the mining industry, guar gum is utilised as a chemical flotation agent by getting absorbed onto hydrated mineral surfaces. In flotation process guar gum works as a depressant that obstructs the absorption of other reagents onto the surfaces of talc and other gangues, which are mined along with the valuable minerals.[31] Guar gum is applied in mining potash, gold, copper and platinum group metals (PGM) as a flocculent and as a depressant.[32]

5.2.5. Explosives Industry

The water proofing, thickening and foam stabilising properties of guar gum are useful in the preparation of explosive products. Oxidised guar gum is the most commonly used polysaccharides to thicken slurry explosives. Guar gum is used as a binding agent in the production of water-resisting ammonium nitrate stick explosive. When the explosive stick is immersed in water, the oxidized gum in the outer wall swells quickly and the resultant gel delays the leaching of the salts. It is also utilized as a thickener and gelling agent for slurry explosives.[33] In recent years, guar has become the primary gelling agent in water-based slurry explosives.[34]

5.2.6. Pharmaceutical Industry

Guar gum and its derivates are widely used in the pharmaceutical industry. They are applied as an agent for gelling, viscosifying, thickening, suspension, stabilisation, clouding/bodying, binding, process aid, pour control for suspensions, anti-acid formulations, preservation, emulsification, water retention/water phase control, tablet binding and disintegration, nutritional foods, controlled drug delivery systems, slimming aids etc. Guar gum is a major non-caloric source of soluble dietary fibre. Guar gum powder is extensively used in capsules as dietary fibre.[35]

5.2.7. Cosmetic Industry

Cationic guar gum is a derivative of guar gum used as a thickener in several cosmetic products. This derivative is applied to impart a number of performance functions such as thickening, conditioning, foam stability, softening and lubricity in cosmetics and toiletries like hair and skin care products, cleansing and bathing products.[36]

5.3. Traditional Uses

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30 http://www.shplindia.com/mcp/download/Guar%20Gum.pdf
31 Ibid
32 http://www.guarglobal.com/opportunity/guar-global-markets
33 http://www.shplindia.com/mcp/download/Guar%20Gum.pdf
34 http://www.ashland.com/Ashland/Static/Documents/AAFI/PRO_250-61_Guar.pdf
35 Science Tech Entrepreneur, September 2007
36 http://www.shplindia.com/mcp/download/Guar%20Gum.pdf

The immature pods of guar are dried, salted and conserved for future use by people. The green pods are cooked like French beans and dried pods fried like potato chips. The mature seeds are also used as a pulse in times of drought.

The guar plant is cut and fed as green feed for cattle. Guar seeds are boiled in a large kettle and fed to cattle as a high source of protein.

Guar is also used for a variety of medicinal purposes. Leaves are eaten to treat night blindness. Guar seeds are utilised as a chemotherapeutic agent for smallpox. Seeds are also used as a laxative. Boiled guar seeds are used as poultices for enlarged livers, and head swellings and on swellings due to broken bones.

The guar crop has also been used as soil quality improver, as a cover crop and as green manure.

6. Substitutes/Alternatives to Guar Gum

As mentioned earlier, the extraordinary volatility in guar prices in recent years has induced the guar gum user industries to look for alternatives. Some oilfield services companies like Baker Hughes, Haliburton, Trican and Nabors companies are reported to have begun in-house research on substitutes for guar gum.

The major alternatives to guar gum that are known to have been developed are described below, along with their limitations:

6.1. Tara Gum

Tara gum is obtained by grinding the endosperm of the seeds of *Caesalpinia spinosa*, of the Leguminosae family. Tara plant is grown in Peru, northern, western and southern South America and its gum belongs to the same chemical family as guar gum. Tara plant has also been introduced in the drier parts of Asia, the Middle East and Africa and has become naturalised in California, USA. Tara gum is a white to yellowish powder, soluble in hot water and partially soluble in cold water. It comprises polysaccharides, mainly galactomannans, with a high molecular weight. Tara gum is a natural additive used in the food and beverage industries and works as a thickener and stabiliser.

Tara gum offers many advantages over guar gum:[37]

- The flow of tara gum is more smooth and natural than guar gum.
- The structure of tara gum is smooth and soft, whereas guar gum can have a slimy texture in some applications.
- Tara gum, when combined with xanthan gum or carrageenan, can form a extremely soft gel structure.
- Tara gum is odourless and tasteless, whereas guar gum has an unpleasant taste and smell.

[37] http://www.en.silvateam.com/Products-Services/Food-Ingredients/Tara-gum/Tara-gum-vs-guar-gum

- When used in the food industry, the flavour release of tara gum is greater than that of guar gum.
- When added to gel, tara gum can increase gel elasticity and retain water within the structure. It also enhances the shelf stability of the gel.
- Tara gum provides freeze-thaw stability as it prevents formation of ice crystals in ice cream.
- Tara gum is stable at high temperature during heat treatment.

However, the major disadvantage of tara gum is that it does not make liquids as viscous as guar gum does, and industries need to buy and use larger quantities of tara gum to get the desired viscosity. Another limitation is that tara gum is produced in very limited quantities compared to guar gum and locust bean gum. This makes it commercially unviable in the market of hydrocolloids or gums (Mathur 2012).

6.2. Locust Bean Gum

Locust bean gum (LBG) is also known as Carob bean gum. It is a natural derivative from the seeds of the carob tree cultivated in the Mediterranean regionof Southern Europe, Northern Africa, and some adjacent areas of the Middle East (Mathur 2012).

Locust bean gum is cost-effective and used mostly in the food industry. It is the preferred texturiser for various food applications because of its natural image, neutral taste and the very creamy texture. LBG positively affects the protein stability and does not interact with other constituents in food due to its neutral behaviour.[38]

However, this gum cannot be produced on a large scale easily and it is not heat stable.

6.3. Xanthan Gum

Xanthan gum is a corn-based product. It is produced by fermenting corn sugar with a microbial known as "Xanthomonas campestris". It is generally used as a thickening and stabilising agent in both food and medicine. It is applied extensively in the food industry to make the products thicker and is a widely used ingredient in gluten-free products.[39] Due to its binding characteristic, xanthan gum can serve as a replacement for gluten in foods designed for people who suffer from celiac disease.[40]

However, like locust bean gum, this gum cannot be produced easily on a large scale and it is not heat stable.

6.4. Cellulose based Materials

Cellulose based materials such as carboxymethylcellulose and carboxymethyl-hydroxyethyl cellulose can also be used as substitutes of guar gum in the pharmaceutical industry.

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[38] http://www.danisco.com/product-range/locust-bean-gum/
[39] http://glutenfreecooking.about.com/od/glutenfreecookingbasics/a/xanthanguargums.htm
[40] http://www.livestrong.com/article/315249-xanthan-gum-side-effects/

Cellulose gum is one of the most regular used thickening agents in the world. It is versatile, cost-effective and easy to use. Cellulose gum is derived from the cell wall of plants, especially cotton seeds and wood pulp. It stabilises proteins, adds mouth feel and texture, retains moisture and forms oil-resistant films in a variety of processed food products.[41] Table 5 presents the comparative properties of guar gum and cellulose gum:

Table 5: Comparative properties of guar gum and cellulose gum

Property	Guar Gum	Cellulose Gum
Cold and hot water soluble	Yes	Yes
Dissolution time	Medium fast	Fast
Transparency of solution	Cloudy	Clear
Flavour	Bean flavour	Flavourless
Viscosity range	5000-7000, 1%	30-50,000, 2%
Viscosity-shear	Shear thinning	Shear thinning
Synergy	Mixes with xanthan	Mixes with guar and methyl cellulose
pH stability	Loss below 3.5	Loss below 3.2
Moisture holding	Good	Good
Ionic/Non-ionic	Non-ionic	Ionic

However, cellulose gum comes with a number of disadvantages. First, its cost is higher than that of guar gum. Second, the thermal stability of cellulose based materials is not good and is not likely to be improved. Third, large-scale manufacture is needed to make these materials price competitive.

6.5. Starch

Starch is another possible alternative to guar gum and offers advantages in terms of relatively lower cost per kilogram and availability of many potential sources. However, a big disadvantage of starch over guar gum is that a very large quantity is required to achieve significant viscosity. Further, it has proved to be a limited success so far in fracking process.

6.6. Synthetic Polymers

Many oilfield service companies like Halliburton, Baker Hughes, Schlumberger, FTS International, or their affiliates along with some chemical companies like Dupont are working on developing synthetic polymers, whose properties might rival those of guar gum. Synthetic polymers such as acrylamide and acrylamido-methyl compounds could be the most possible replacement in shale gas fracking due to their superior thermal properties and they are easy to hydrate and crosslink well. However, these polymers have potential to cause damage to the fractures in the formation as residues remain, which reduces the flow. Hence, only when guar prices rise to high levels does the use of these synthetic polymers becomes viable (Trostle and Norman 2013).

6.7. PermStim

PermStim has been developed by Haliburton, one of the largest oil and gas service companies in the world. It is a fluid derivatised natural polymer that contains no insoluble residue.

[41] http://www.danisco.com/product-range/cellulose-gum/

The major advantages of PermStim fluid are given below:[42]

- It is a clean fluid system that provides high regained proppant pack permeability.
- Unlike guar-based fluid systems it does not contain any insoluble residues. This makes PermStim more robust and lead to better well performance.
- Provides better proppant transport.
- Useful across a wide ranges of temperatures, from a low of 100°F (38°C) to providing a 30 minute pumping time at 275°F (135°C).
- An improved well cleanup with greater effective frac length.
- Its relatively higher regained permeability helps to maximise fracture treatment cost effectiveness.
- It is salt tolerant – up to 7 per cent KCl or NaCl

The PermStim fluid system is said to have been successfully used in over 40 wells at temperatures up to 300 degree Fahrenheit last year. However, despite Haliburton's claim that PermStim is cleaner than guar gum solution the chemical composition of the substance is still not revealed. Another limitation is its cost which is substantially higher than guar based solution (Cheminfo 2014).

6.8. ClearStar

ClearStar is another alternative to guar developed by Baker Hughes. ClearStar system applies an efficient, refined cellulose derivative polymer to achieve better viscosity and accomplish a low pH to reduce the potential for clay swelling that can limit production flow. This system has been reported to deliver stable performance at temperatures up to 275°F. The fluid enhances sand transport through the well bore during pumping activities to ensure accurate placement within the fractures. ClearStar has a high molecular weight compared to guar-based fracturing fluids. Therefore, it needs a relatively smaller amount of polymer to get the required viscosity.[43]

The major properties of this fluid are summarised below:

- Leaves no residue behind.
- Increased load recovery.
- Creates clean and efficient fractures.
- Can safely and reliably incorporate all common fracture fluid additives.
- Its controllable viscosity performs well at varying downhole pressures and temperatures (66°C-135°C).
- High molecular weight lowers polymer loading requirements.
- Its superior friction properties reduce the horsepower needed for pumping.

[42] http://www.halliburton.com/en-US/ps/stimulation/fracturing/permstim-fracturing-service.page
[43] http://www.worldoil.com/Baker-Hughes-announces-new-Guar-alternative-frac-fluid.html

- Low volatility of price.

It is reported that in Colorado's Wattenberg field the ClearStar fracturing fluid has produced, on average, 11 per cent more cumulative oil over 350 days of production in comparison to wells stimulated by guar-based fluids.[44]

However, despite many efforts to develop guar alternatives there has been a general lack of success in finding a perfect alternative to guar gum.[45] According to the Journal of Petroleum Technology 2012, as quoted in Trostle and Norman 2013, "no guar substitute has yet been developed that is as effective for high-viscosity hydraulic fracturing, although Halliburton, Baker Hughes, Schlumberger, FTS International, or their affiliates (with a combined share of 54 per cent of USA fracking activity, 2011), as well as the chemical company Dupont, are working on developing synthetic polymers whose properties might rival those of guar gum."

According to PacWest, a US-based Consulting firm, these substitutes in the shale oil and gas industry are likely to capture just about 10 per cent share from of guar. It also states that "the substitutes of guar do have the effect of providing a new ceiling on guar pricing, the point at which it becomes more economic to switch if guar prices escalate dramatically. With prices where they are today [November 2012], the incentives for significant new investments on guar substitutes have fallen off, but several players will continue to fund their programs as a hedge against future price shocks."[46]

Furthermore, it is reported that the cost of these replacements is about US$ 8/Kg which is substantially higher than that of guar (Cheminfo 2014). Therefore, until guar gum prices in the US rise above US$ 8/Kg, alternatives would have a limited impact on demand for guar gum. Guzman (2013) has reported that guar alternatives will not capture more than 20 percent, more likely 10 percent, of hydraulic fracturing market share if guar prices stay below US$ 8000-10,000/MT.

Overall, despite the development of several alternatives to guar in different industries, they are not likely to replace guar in a big way. Industry stakeholders who were consulted during the field survey expressed the view that if the price of guar seed were to stabilise at Rs 45,00-55,00/quintal for some time, the old demand structure will be restored and will resume its normal pace of growth.

7. Key Issues and Challenges to Guar Industry

Although guar products have emerged as one of the top most agricultural export commodities in India in recent years and generated substantial benefits to all stakeholders, the guar-based industry is facing a number of challenges that need to be resolved. Some of the major challenges are discussed below.

7.1. Erratic Production and Supply

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44 Ibid

45 Trostle and Norman 2013

46 http://pacwestcp.com/2012/11/guar-market-stabilizes-around-3-4pound-near-term-demand-increases-modest-but-long-term-strong/, accessed on 05 August 2014.

The most important challenge that both manufacturers and end users of guar gum face is the erratic nature of production and supply. Due to a weak monsoon in 2009-10 the total production of guar seed plunged to less than 0.60 million MT from about 2.0 million MT in 2008-09. Uncertainty in supply was one of the major reasons for the sharp increase in prices of guar in 2011-12. Both high prices and volatility in supply forced many companies in US at that time to look for alternatives to guar gum. This had a negative impact on the potential development of the Indian guar industry.

Uncertainty in production is mainly due to the fact that a large proportion of guar cultivation is done in the dry and un-irrigated regions of the country, that too on marginal lands. Thus the entire supply is determined by the amount and spatial distribution of rainfall, especially in Rajasthan.

7.2. Low Productivity

Productivity in terms of yield/hectare is generally very low in India. The productivity level in Rajasthan was 3.25qt/ha under irrigated conditions and 2.75qt/ha under rain-fed conditions in 2010. This is much lower compared to Haryana, where the productivity level was 11qt/ha in the same year (Sharma 2010).[47] There is a wide variation in region and district wise productivity. Lower productivity is caused not only by poor rainfall but also by poor management and lack of inputs. One of the key reasons for low productivity is non-availability of high yielding guar seeds in some guar producing areas, with the result that most farmers still use poor quality seeds. During consultations, the farmers in Rajasthan pointed out that there was a big difference in yield between certified and local seeds. In some guar growing regions, there is general lack of availability of short duration, high yielding and drought resistant variety of seeds, and when available, their prices are high. Although there is an increasing trend among farmers to use certified seeds, the seed replacement rate for guar is still one of the lowest among all crops in Rajasthan, at 7.38 per cent in 2007-08.[48]

7.3. Lack of Research and Development (R&D) Facilities and Dissemination

Given the nature of guar production, potential uses of its derivative products and high dependence on international markets, there is lack of general R&D facilities focused on the guar industry in the country. There are no reputed R&D institutions in the country focusing on guar seed production, development of industry- specific products, manufacturing and processing technology, or plant and machinery. Although there are some institutions in the country focusing on the development of certified seeds and they have developed some certified guar seeds, there is no proper distribution infrastructure. Consequently, farmers wanting to use certified seeds cannot find it in the market at an affordable rate. Existing research institutions and agricultural universities face a funds crunch for undertaking research for the development of new varieties and for product processing and technology development.[49]

7.4. Problems related to Marketing

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[47] http://www.academia.edu/5576209/Guar_Industry_Vision_2020_Single_Vision_Strategies
[48] http://archive.india.gov.in/allimpfrms/alldocs/9717.pdf, accessed on 26 June 2014.
[49] http://www.academia.edu/5576209/Guar_Industry_Vision_2020_Single_Vision_Strategies

One of the major problems for guar stakeholders is the lack of market intelligence. There is no reliable source of information on domestic consumption and overseas demand for guar seed and its derivative products. The *mandi* fee for guar seed varies in different states. Given the nature of the product, farmers and traders would like to store the produce but warehousing facilities for the storage of guar seed are inadequate. One of the problems with existing warehouses is that they lack facilities to ensure that the quality of stored seeds is maintained. There is also a lack of regulation on quality maintenance in warehouses. Another major marketing related problem is inadequate quality certification for guar seeds and guar derivative products. In addition, due to lack of knowledge, high viscosity seed varieties are mixed with the normal variety.

Processing of guar is done entirely by the private sector, and all the processing/manufacturing units are based in the major producing states of Rajasthan and Haryana. Farmers producing guar in other states like Andhra Pradesh, Maharashtra and Karnataka face marketing problems.

7.5. Trade Barriers

The major industrialised countries, the US and the EU, have made the product duty free for imports, but the emerging economies generally impose duties on the guar product. The tariff structure in China is of particular interest to India as that country is the second most important market for India after the US. There is substantial tariff escalation in China, which currently imposes a 15 per cent duty on guar gum powder, and 7 per cent on guar splits.[50]

Indian exporters are reported to be facing several problems regarding quality certification. Also, since guar products are largely exported through seaports, exporters face problems while transporting their goods from their factories to ports. One of the major port related issues is that stuffing has to be done at the port itself and containers are not made available at factory sites.

Exporters need certificates like HACCP, ISO 9000, ISO 22000, HALAL and Kosher for food grade guar; getting these certificates from government authorities is very time and resource consuming.

7.6. Limited Value Addition and Product Diversification

There is lack of initiative from Indian industry to produce diversified value added products required for use in specific industries. R&D for innovation in the industry is sadly lacking.

7.7. Development of Substitutes of Guar Gum

The guar industry is likely to face challenges from cheaper substitutes coming up in various sectors and especially in oil and gas sector. For instance, tamarind kernel is reported to have replaced guar gum to a significant level in the textile sector for use in different types of dyes, fabrics and textile printing applications.[51] Similarly, Cassia Tora is being extensively used in

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[50] http://articles.economictimes.indiatimes.com/2011-05-31/news/29604123_1_guar-seed-guar-gum-debjani-roy

[51] http://www.dsir.gov.in/reports/tmreps/guar.pdf

the food industry and is expected to replace guar gum in pet food, etc. There are a number of other substitutes of guar gum being developed for use in different industries, including shale gas and oil. The threat of substitution will become greater if the uncertainty in supply continues and prices move beyond a certain range.

7.8. Other Problems

As the industry has grown over the years, the demand for specialised labour, professional advisory service and technical support has increased and a shortage of trained manpower has been felt by many processors/manufacturers in the industry. There is also lack of know-how on technology and product bio-chemistry.

8. Future Prospects

A favourable development for stakeholders in the guar industry in India is that global demand for guar products in general and guar gum in particular has expanded rapidly during the last few years. This has been due mainly to the sharp increase in the use of guar gum in the shale gas and oil industry in the US. The food industry was earlier the major user industry for guar products but shale gas and oil industry has overtaken it and become the dominant user of guar gum in recent years. The US is the largest importer and India is the largest exporter of guar products in the world. Provided guar prices remain within a narrow range as compared to the level at which it appears to have settled during the latest one year period up to August 2015, the following factors are likely to provide impetus for a buoyant Indian guar gum industry.

- The shale revolution has made the US the largest producer of natural gas in the world and has already brought its crude oil production to a 20-year high. According to the International Energy Agency, the US is projected to surpass Saudi Arabia as the largest oil producer by 2017. The US shale gas industry is also expected to grow over the next two decades. Since the shale gas and oil industry is the largest user of guar gum, its expected growth is likely to sustain the demand for guar gum in the long term. However, there has been a substantial decline in global crude oil prices in the last 12 months and the current forecast is of continued weakness in these prices. This has already begun to affect the production of shale gas and oil in the US. The future prospects of guar products have thus become uncertain.
- Exports to China, which is the second largest destination for Indian guar products exports, has been increasing at a rapid pace in recent years. China has the largest technically recoverable shale oil and gas resources in the world and the production is likely to increase in future. This would further contribute to an increase in the demand for guar gum in the world market.
- With rising living standards the consumption of processed food is likely to increase around the world, buoying up the demand for guar gum for the food industry. The fact that organic food products are being increasingly preferred will reinforce this trend.
- In a world driven by technology, the threat of substitution is ever present for all materials and guar gum is no exception. However, the assessment is that as long as guar prices remain stable within a narrow range around the levels prevailing over last one year up to August 2015, guar products would be able to withstand the threat of

substitution by both natural and synthetic materials. In addition, pervasive environmental concerns will give guar gum an edge over synthetic substitutes.

9. Recommendations

Having emerged as one of the largest agricultural export items from India, guar has also become a major alternative commercial crop for farmers in the dry regions of the country. Guar processing has developed into a major industry comprising hundreds of industrial units and providing employment opportunities to thousands. Guar gum derivatives have a variety of uses in different industries and its by-products are widely used for animal and human consumption. However, farmers and industry face major challenges in terms of price volatility, low productivity, erratic guar production, limited R&D, etc. Stakeholders need to take steps that will help not only to overcome the current problems the industry and farmers face, but also to strengthen the future prospects of the industry.

9.1. Government

- One of the major issues that guar farmers face is the lack of availability of HYV of guar seed. There is a substantial difference in productivity per hectare between "*desi*" and certified seeds. The field survey conducted for this study revealed that certified seeds not only increase productivity substantially in comparison to that of "desi" seeds, but also result in higher unit price realisation. However, farmers in some areas are not able get quality seeds at affordable prices. The government has to play a leading role not only in R&D for developing HYVs but also in providing farmers access to the improved seeds.
- Given the properties of guar seed, its applications/uses in different industries needs to be fully explored. This is another area in which government needs to facilitate R&D through public institutions. This will diversify the industrial use of guar and reduce the guar industry's overdependence on the shale oil and gas industry.
- Government needs to facilitate value addition in the guar processing industry through trade policy measures. Under the Foreign Trade Policy 2009-14 exports of both guar gum refined split and guar gum treated and pulverised or guar gum powder were being promoted under the Focus Product Scheme (FPS) and given "Duty Credit Scrip"[52] equivalent to two per cent of the FOB value of exports.[53] Thus the export incentives granted by the government had put higher value added products on the same footing as lower value added product. This anomaly has been remedied in the new Foreign Trade Policy 2015-20, which has withdrawn the above benefits.
- As we have seen above, the precipitous decline in crude oil prices in the last 12 months has led to contraction of shale oil and gas industry in the US. This is likely to be translated soon in a fall in demand for guar gum. In this context there is a case for considering limited export incentives for the value added product of guar industry i.e. guar gum powder. Government could consider inclusion of this product under the

[52] "Duty Credit Scrip" is a paper authorisation that allows the holder to import inputs that go into manufacture of products that are exported or machinery used for producing such goods without paying duties equivalent to the printed value.

[53] http://dgft.gov.in/Exim/2000/PN/PN12/pn0312.htm

Merchandise Exports from India Scheme (MEIS). The incentive can be justified only as a temporary measure. In any case, these incentives can be continued only until such time as India remain eligible for the flexibility granted to low income countries, including India, listed in Annex VII of the WTO Agreement on Subsidies and Countervailing Measures.

- Futures trading in guar seed and splits on commodity exchanges seems to have further increased the price volatility of guar products, causing concern to both farmers and industry. The Government should therefore strengthen the regulatory frame work of Futures Exchanges so that they remain a forum for price discovery, hedging and price risk management.
- Since cultivation of guar has also started in new states like Andhra Pradesh, Karnataka, etc., these state governments need to provide marketing avenues for the farmers.
- Logistics facilities connecting the industrial hubs and ports are poor. It was found during interactions with exporters that containers and transportation facilities for processed products from the processing point to the port of export and storage facilities are lacking, and hygiene standards at inland container depots (ICDs) do not conform to the standards required for food grade guar products. Government needs to look into these issues keeping in mind the specific requirements of guar industry.
- Multiple certificates are required to export food-grade guar products and getting those certificates is very time and resource consuming. Regional laboratories and certification agencies should be established near the processing centres.

9.2. Industry/Traders

- First of all, the guar processing industry should make its existing association more effective and active, catering to the collective interest of the industry. This body should have information about the industry and market intelligence, which should be shared with all its members.
- Very few Indian companies produce industry specific guar derivatives on a competitive basis. Industry should take the initiative to obtain the needed technology and/or collaborate with foreign companies to set up derivative manufacturing facilities in India.
- There is general lack of awareness among industries about the properties of guar products. The guar processing industry has to work together to promote and market the products among various industries.
- Although India is the largest supplier of guar products in the world, all the patents are with companies from western countries. Investment in R&D by industry alone can result in inventions that could be patented.
- Industry should also work towards expanding the area under contract farming and put arrangements in place to ensure that farmers get a fair price.

9.3. Farmers

- Farmers should be open to use certified and truthfully levelled (TL) seeds and adopt production techniques developed by different R&D institutions and seed companies in the country.

- Farmers need to create their own association to take care of their collective interests and work with the industry association to learn about the new developments and requirements of the industry. The association should also work to promote progressive farming.

- They should effectively utilise information technology to get market information, especially on prices and respond to those developments.

- Progressive farmers should also take part in futures trading of guar products to get the maximum benefit from price movements.

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