

Economics of Production, Marketing and Utilization

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INTRODUCTION

The marketing of corn and its products incorporates operations, activities, distribution channels, and commercial practices to take products from those who produce them to those who consume them. Marketing is an important link in the supply chain so that all participating economic agents can capture value. Overall marketing adds four sources of value in the supply chain: place, connecting producers and consumers in distances; time, synchronizing seasonal production with along the year utilization; possession, operating the needed transactions to move corn from a single producer to a particular consumer; and physical chemical, transforming the raw grain into different products that individually face specific demands. Marketing is always pushing for efficiencies in the supply chain such that the costs of operations and activities are lower than before and lower than the added-value in order to cash some profit.

Marketing has exchange activities such as purchase, sale, and intermediation. It performs physical activities such as handling, cleaning, grain moisture stabilization, storage, transportation, and transformation. Furthermore, it also develops facilitation activities such as standardization, regulation, and certification; risk management; financing and payments facilitation; administrative and related services such as customs or information services.

Marketing involves economic agents and institutions such as the producer, the local buyer, the grain elevator, and transportation either by trucks, train loads, barges, or ships/vessels. It involves primary and secondary processors that transform corn. Marketing also requires brokerage houses, financial institutions, bonded warehouses and insurance companies, shipping agencies and intermodal transport handling, customs agencies, government institutions, and certification companies. In order to facilitate commodities³ transactions, marketing requires spot and derivative markets to arrive at impartial prices, interchanging bids, and offers among participants. Prices are the invisible hand that coordinates economic activities in the supply chain, and for all the products in the supply chain, prices determine offered quantity and final demand quantity as we interpret the “invisible hand” concept from [Smith \(1776\)](#).

CORN (MAIZE) AS A CROP

Corn (*Zea mays*) is an annual crop domesticated in Mexico over 10,000 years ago (see [Chapter 1](#)). It is grown during the summer and its productive cycle is between 120 and 210 days long—depending on genetics and altitude—with longer cycles for colder and higher places. There is abundant genetic diversity, which allows corn production in diverse production zones. Different varieties and hybrids are commercially grown at different latitudes and altitudes ranging from sea level to 2400 m above sea level. With a productive cycle between 4 and 7 months long, supply may respond to expected crop prices in under a year.

Corn is the grain with the most demand in the world and is among the fastest-growing in yearly volume. Corn has surpassed rice and wheat in production and utilization and is the second world’s most produced crop behind sugarcane. These three cereal grains are the nutritional basis for the majority of humankind. Wheat and rice are autogamous crop plants, which means the plant self-fertilize in a closed flower, whereas corn is an allogamous plant, which means it

3. Commodities are standardized goods that can be substituted for a similar good (perfect substitute) that can come from a different seller even from other country.

cross-pollinates. The male flower of corn is found in the tassel, while the female flower is in the ear. Cross-pollination has allowed much wider genetic variation and humans have increased corn's adaptation possibilities for different parts of the world mainly through technological developments in agronomy, thus increasing the plant's value for humankind. Cross-pollination makes also possible the growth of more productive hybrid corn crops and this attribute attracts R&D investments in genetics (see [Chapter 2](#)) and genetically modified organisms (GMOs) (see [Chapter 3](#)) and gives more space to make business for commercial seed companies compared to autogamous crops such as wheat and rice.

Corn is also one of the grains with the largest alternatives of industrial technological development (postharvest). Industrially, technological progress has been made both in the separation of grain components as well as in the development of products that use these components. In short, the value of corn cannot be understated because it has become the most relevant cereal for humankind.

CORN DEMAND

Worldwide Corn Utilization

Across the world, corn on the cob is used as a vegetable and the mature kernels are utilized for production of an array of human food (see [Chapters 16 and 17](#)) or for animal feeding purposes (see [Chapter 23](#)). The corn kernel can be separated physically or chemically into its components to obtain refined dry-milled fractions (see [Chapter 15](#)), starch (see [Chapter 18](#)), and several coproducts. These raw materials are converted into value-added breakfast cereals, snacks, bakery items, dextrose, glucose, dextrans, potable alcohol or distilled spirits, bioethanol, and corn oil.

Around 1.063 billion metric tons (41.860 billion bushels⁴) of corn are yearly consumed worldwide. Most of this utilization is of national product, only 14% (150 million metric tons per year) of the worldwide production is traded among countries. Corn utilization has averaged a yearly growth of 2.2% in the past 5 years, which is over two times the rate of the world population growth. Many countries have recently started incorporating various corn uses from other countries, which helps sustain this dynamic growth. [Table 4.1](#) depicts that this growth is led by countries with double-digit utilization increase like Iran and Vietnam, as well as countries with high growth like India, Russia, and Mexico. [Table 4.1](#) also shows that the United States and China make up more than half of the worldwide corn supply ([USDA, 2017b, Grain: World markets](#)).

As [Table 4.1](#) shows, worldwide per capita corn utilization averages to 135.7 kg per year. Because of its advanced industrialization and highly effective agriculture systems, the United States has the highest per capita utilization estimated in 978 kg per year. Other countries still show a low per capita utilization. For example, the average Indian citizen consumes only 20.36 kg per year, although the annual growth in that populated country is over 5%.

Utilization per Country and per Capita

[Table 4.1](#) shows a list of some corn consumer countries ordered according to their most recent utilization estimate. The United States and China utilize/consume more than half of the worldwide output. Given the depth of the USA industry, the per capita utilization is more than seven times the worldwide per capita average.

Corn utilization is influenced by culture and industrial development; this gives way to the important differences in utilization summarized in [Table 4.1](#). Mexico has had a corn-based diet for over 10,000 years and some of its more traditional products have started to reach practically all countries around the globe thanks to the globalization, which has allowed products and processes to permeate across borders. It would be safe to infer that global corn utilization can sustain its growth rate at that of twice the population growth for at least another 20 years. As an example, after 18 years at said growth rate, the average South Korea per capita utilization would barely be equal to the current per capita global level.

Technological developments have improved corn utilization in several ways. One way to process it for human utilization as a whole grain is in the process of nixtamalization by grinding it into a dough for tortillas, tortilla chips, and other snacks (see [Chapter 17](#)). This process that originated in prehispanic Mexico has reached practically all countries around the world and consequently the global market has shown an increased appreciation for these lime-cooked corn products. The main global companies that supply this market are “Gruma, S.A.B. de C.V.”; “Cargill Inc.”; “Grupo Bimbo, S.A.B. de C.V.”; and “Grupo Minsa, S.A.B. de C.V.”

4. 1 corn bushel = 56 pounds; and 39.3683 bushels = 1 metric ton.

TABLE 4.1 World Corn Utilization/Disappearance (*Thousand Metric Tons*), Structure (%), Average Annual Growth (%), Population (*Millions*), and Per Capita Utilization (*kg Per Capita Per Year*)

Country/Region	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	Structure 2017/18	Growth 2012/17	Population	Per Capita
United States	292,958	301,792	298,785	313,577	315,609	316,880	29.8%	1.6%	324.0	978.04
China	208,000	202,000	217,500	232,000	238,000	238,000	22.4%	2.7%	1373.5	173.27
European Union	76,796	77,880	73,500	72,500	74,700	74,700	7.0%	-0.6%	513.9	145.35
Brazil	55,000	57,000	57,500	60,500	61,500	61,500	5.8%	2.3%	205.8	298.80
Mexico	31,700	34,550	37,300	39,900	40,700	40,700	3.8%	5.1%	123.2	330.45
India	19,600	22,350	23,550	24,600	25,800	25,800	2.4%	5.7%	1266.9	20.36
Egypt	13,200	13,900	14,850	15,100	15,900	15,900	1.5%	3.8%	94.7	167.96
Japan	15,000	14,600	15,200	15,100	15,100	15,100	1.4%	0.1%	126.7	119.18
Vietnam	8200	9400	12,250	13,100	13,900	14,600	1.4%	12.2%	95.3	153.26
Canada	12,675	12,820	12,354	12,920	14,100	14,100	1.3%	2.2%	35.4	398.72
Indonesia	11,900	12,200	12,100	12,200	12,200	12,200	1.1%	0.5%	258.3	47.23
Iran	6800	7400	8800	11,100	12,100	12,100	1.1%	12.2%	82.8	146.13
Argentina	8800	9300	9200	11,000	11,300	11,800	1.1%	6.0%	43.9	268.87
South Africa	11,500	11,650	10,970	12,400	11,700	11,700	1.1%	0.3%	54.3	215.47
Korea, South	9891	10,250	10,123	9900	10,300	10,300	1.0%	0.8%	50.9	202.26
Russia	7500	8100	8700	9600	10,100	9900	0.9%	5.7%	142.4	69.54
Others	156,958	162,316	162,702	165,772	171,983	171,648	16.1%	1.8%	3045.2	56.37
World Total	953,033	984,693	965,618	1,054,050	1,062,119	1,063,595	100.0%	2.2%	7837.1	135.71
World Total (<i>Million Bushels</i>)	37,509	38,755	38,004	41,484	41,802	41,860				

Source: Made with data from the Foreign Agricultural Service/USDA. Office of Global Analysis, July 2017. Population Estimates @ July 2016, CIA. https://www.cia.gov/library/publications/the-world-factbook/rankorder/rawdata_2119.txt.

Corn kernels—especially those classed as yellow—are widely used for the formulation of feedstuffs for domestic monogastric and ruminant animals, and therefore, converted into poultry, swine, beef sheep/goat meats, milk, and eggs (see [Chapter 23](#)).

Corn can be separated into its chemical components through the use of a wet-milling (see [Chapter 18](#)), starch being the main product. The major food use of starch is for the production of an array of syrups and sweeteners, mainly the family of the high fructose corn syrups (HFCS, see [Chapter 20](#)). HFCS industry is concentrated and [Absolute Reports \(2017\)](#) reports that the major companies are: Cargill; ADM; Tate and Lyle; Ingredion Incorporated; Showa Sangyo; The Hershey Company; Global Bio-chem; Baolingbao; Luzhou Group; and Xiwang Group. Besides, starch is commonly transformed into bioplastics, bioethanol, and other value-added chemical products. The United States is currently expanding the wet-mill industry because it generates an array of value-added products demanded by the food, feed, pharmaceutical, and bio-refinery industries. Thus, the global demand for corn is expected to increase as the diversity of corn uses spreads from the United States to other parts of the world.

Corn can also be separated physically through the use of a dry milling process (see [Chapter 15](#)) because refined grits are common raw materials for the industrial production of an array of Ready-To-Eat (RTE) breakfast cereals (see [Chapter 16](#)) mainly consumed by inhabitants of developed countries. There is a potential to increase cereal utilization in developing countries as the cereal firms develop new markets. The refined grit number 5 (retained by the US No 5 mesh sieve) is most commonly used for the preparation of flakes still considered as the most popular RTE breakfast cereal (see [Chapter 16](#)). About 70% of the worldwide breakfast cereal sales are experienced in developed countries, which allows the development of potential unattended new markets and consumers around the increasing globe population. However, it is important to realize that there are new and novel alternatives for breakfast cereals that are not based on corn. There is an increasing concern for worldwide obesity problems, especially among children, which has affected utilization of sugar and sugar-intensive products. This could negatively affect the growth in utilization of some RTE breakfast cereals ([Berning and Rabinowitz, 2017](#)).

Continued research on whole corn and its physically or chemically derived components has expanded new product developments that could eventually become mass produced such as: heat-resistant biodegradable bioplastics, glues, clothes, pharmaceutical products, other packaging materials, and even sodium-free salt. This guarantees a diversified and growing global demand with a bright future.

USA Corn Utilization

The recent increasing demand of the USA corn has been driven by biorefineries which produce renewable ethanol for its use in automotive fuel oxygenation ([Table 4.2](#)). Interestingly, in 1985, the animal feed industry demanded 78% of the corn use, whereas in this century the demand for this specific use decreased to only 44% without significantly affecting the amount channeled to the animal feed industry. It is important to note that feed conversion efficiencies to meat have improved significantly, particularly in poultry and swine ([Colman et al., 2011](#)).

As [Table 4.2](#) shows, by 1985, 78% of the United States' corn use was for “feed and residual uses”. This category grew 0.2% annually in the following 32 years, but the United States' corn use grew 2.8% annually throughout the same period. The category “food, alcohol, and industrial use” was only 8.3% of the United States' corn use. This particular category grew annually 7.2%, so, in 2017, about 56% of the 365 million tons of the United States' corn use was in this category ([USDA, 2017a, Feed Grain Data](#)).

[Table 4.3](#) shows an important increase in industrial use of corn starting from year 2000, mostly driven by the production of ethanol, where each metric ton of corn commonly yields between 330 and 370 L (liters) of anhydrous ethanol (<0.5% moisture) (see [Chapter 22](#)).

[Fig. 4.1](#) shows that in the past 40 years, United States' production grew annually at a pace of 4.9 million tons. The driver of this impressive growth is the increase in the farmer yield, pushed mainly by biotechnology, vegetal nutrition, and increase in capital intensity, particularly in precision agriculture machinery (see [Chapter 5](#)) and working capital.

[Figs. 4.2 and 4.3](#) show that, in the last 37 years, United States' domestic utilization structure evolved gaining relevance for the use of corn to produce alcohol for fuel.

Corn and ethanol prices are not correlated, and because the market price of anhydrous ethanol is more related to the cost of the barrel of petroleum or refined gasoline, profitability of the bioethanol industry experiences volatility. [Fig. 4.4](#) shows 17 years of evolution of the USA farmer corn prices based on 1000 L of ethanol. It shows that the corn for 1000 L of ethanol has been between <200 USD and >700 USD. In order to promote the USA ethanol industry, blenders used to receive a tax credit of 60 USD-cents/gal until 1990; 54 USD-cents/gal from 1990 to 2004; 51 USD-cents/gal from 2004 to 2008; 45 USD-cents/gal from 2008 to 2011; and zero tax credit since 2011 ([Diggs, 2012](#)).

TABLE 4.2 Evolution of Corn Use in United States (Million Metric Tons and %)																			
	Corn Sources				Corn Uses							Domestic Use Structure				Annual Growth			
	Beginning Stocks	Production	Imports	Total Supply	Food, Alcohol, and Industrial Use	Seed Use	Feed and Residual Use	Total Domestic Use	Exports	Total Disappearance	Ending Stocks	Food, Alcohol, and Industrial Use	Seed Use	Feed and Residual Use	Ethanol USA Tax Credit (cent/gal)	Food, Alcohol, and Industrial Use	Seed Use	Feed and Residual Use	Total Domestic Use
1985	41.9	225.4	0.3	267.6	28.8	0.5	104.5	133.8	31.2	165.0	102.6	21.5%	0.4%	78.1%	60	8.3%	-8.0%	0.0%	1.6%
1986	102.6	208.9	0.0	311.6	30.9	0.4	118.4	149.7	37.9	187.6	124.0	20.6%	0.3%	79.1%	60	7.4%	14.4%	13.3%	11.9%
1987	124.0	181.1	0.1	305.2	31.4	0.4	121.7	153.4	43.6	197.0	108.2	20.4%	0.3%	79.3%	60	1.5%	3.0%	2.8%	2.5%
1988	108.2	125.2	0.1	233.5	32.5	0.5	99.9	132.9	51.5	184.4	49.0	24.5%	0.4%	75.2%	60	3.6%	7.0%	-17.9%	-13.4%
1989	49.0	191.3	0.0	240.4	34.3	0.5	111.3	146.1	60.1	206.3	34.2	23.5%	0.3%	76.2%	60	5.6%	2.7%	11.4%	10.0%
1990	34.2	201.5	0.1	235.8	35.7	0.5	117.1	153.3	43.9	197.1	38.6	23.3%	0.3%	76.4%	60	4.0%	2.1%	5.2%	4.9%
1991	38.6	189.9	0.5	229.0	38.4	0.5	121.9	160.8	40.2	201.1	27.9	23.9%	0.3%	75.8%	54	7.6%	4.7%	4.1%	4.9%
1992	27.9	240.7	0.2	268.8	39.0	0.5	133.4	172.9	42.2	215.2	53.7	22.6%	0.3%	77.1%	54	1.6%	-7.4%	9.5%	7.5%
1993	53.7	161.0	0.5	215.2	40.5	0.5	118.9	159.9	33.7	193.6	21.6	25.3%	0.3%	74.4%	54	3.6%	7.5%	-10.9%	-7.6%
1994	21.6	255.3	0.2	277.1	43.1	0.5	138.7	182.3	55.3	237.6	39.6	23.7%	0.3%	76.1%	54	6.5%	-9.0%	16.7%	14.0%
1995	39.6	188.0	0.4	228.0	40.8	0.6	119.2	160.6	56.6	217.1	10.8	25.4%	0.3%	74.2%	54	-5.2%	19.7%	-14.1%	-11.9%
1996	10.8	234.5	0.3	245.7	43.0	0.6	134.0	177.6	45.7	223.2	22.4	24.2%	0.3%	75.5%	54	5.3%	1.7%	12.5%	10.6%
1997	22.4	233.9	0.2	256.5	46.1	0.6	138.4	185.1	38.2	223.3	33.2	24.9%	0.3%	74.8%	54	7.2%	3.5%	3.3%	4.2%
1998	33.2	247.9	0.5	281.6	46.8	0.6	138.4	185.8	50.4	236.2	45.4	25.2%	0.3%	74.5%	54	1.4%	-3.2%	0.0%	0.4%
1999	45.4	239.5	0.4	285.3	48.6	0.6	143.3	192.5	49.2	241.7	43.6	25.3%	0.3%	74.4%	54	4.0%	3.7%	3.5%	3.6%
2000	43.6	251.9	0.2	295.7	49.7	0.6	147.8	198.1	49.3	247.4	48.2	25.1%	0.3%	74.6%	54	2.2%	-3.0%	3.2%	2.9%
2001	48.2	241.4	0.3	289.9	51.9	0.6	148.5	200.9	48.4	249.3	40.6	25.8%	0.3%	73.9%	54	4.3%	5.2%	0.5%	1.4%
2002	40.6	227.8	0.4	268.7	59.3	0.6	140.8	200.7	40.3	241.1	27.6	29.5%	0.3%	70.2%	54	14.3%	0.6%	-5.1%	-0.1%
2003	27.6	256.2	0.4	284.2	64.2	0.6	146.8	211.6	48.3	259.9	24.3	30.4%	0.3%	69.4%	54	8.3%	1.7%	4.2%	5.4%
2004	24.3	299.9	0.3	324.5	68.2	0.6	155.8	224.6	46.2	270.8	53.7	30.4%	0.3%	69.3%	54	6.3%	0.2%	6.1%	6.2%
2005	53.7	282.3	0.2	336.2	76.2	0.6	155.2	232.0	54.2	286.2	50.0	32.8%	0.3%	66.9%	51	11.6%	-2.4%	-0.3%	3.3%
2006	50.0	267.5	0.3	317.8	89.3	0.7	140.6	230.7	54.0	284.7	33.1	38.7%	0.3%	61.0%	51	17.3%	20.7%	-9.4%	-0.6%
2007	33.1	331.2	0.5	364.8	112.3	0.7	148.7	261.6	61.9	323.5	41.3	42.9%	0.3%	56.8%	51	25.7%	-7.0%	5.7%	13.4%
2008	41.3	305.9	0.3	347.5	127.1	0.7	130.3	258.0	47.0	305.0	42.5	49.3%	0.3%	50.5%	51	13.2%	2.5%	-12.4%	-1.4%
2009	42.5	331.9	0.2	374.6	150.8	0.7	129.4	281.0	50.3	331.3	43.4	53.7%	0.3%	46.1%	0	18.7%	1.9%	-0.6%	8.9%
2010	43.4	315.6	0.7	359.7	162.6	0.8	121.2	284.5	46.5	331.1	28.6	57.2%	0.3%	42.6%	0	7.8%	6.6%	-6.4%	1.3%
2011	28.6	312.8	0.7	342.2	162.6	0.8	114.6	278.0	39.1	317.1	25.1	58.5%	0.3%	41.2%	0	0.0%	4.8%	-5.4%	-2.3%

Continued

TABLE 4.3 Major Producers' Countries of Fuel Ethanol in 2016

Region	Millions of Gallons	Millions of Liters	Structure
United States	15,329	58,027	57.7%
Brazil	7295	27,615	27.4%
European Union	1377	5213	5.2%
China	845	3199	3.2%
Canada	436	1650	1.6%
Thailand	322	1219	1.2%
Argentina	264	999	1.0%
India	225	852	0.8%
Rest of World	490	1855	1.8%
	26,583	100,628	100.0%

Source: RFA analysis of public and private data sources. Taken from: <http://www.ethanolrfa.org/resources/industry/statistics/#1454099103927-61e598f7-7643> as August 12th, 2017.

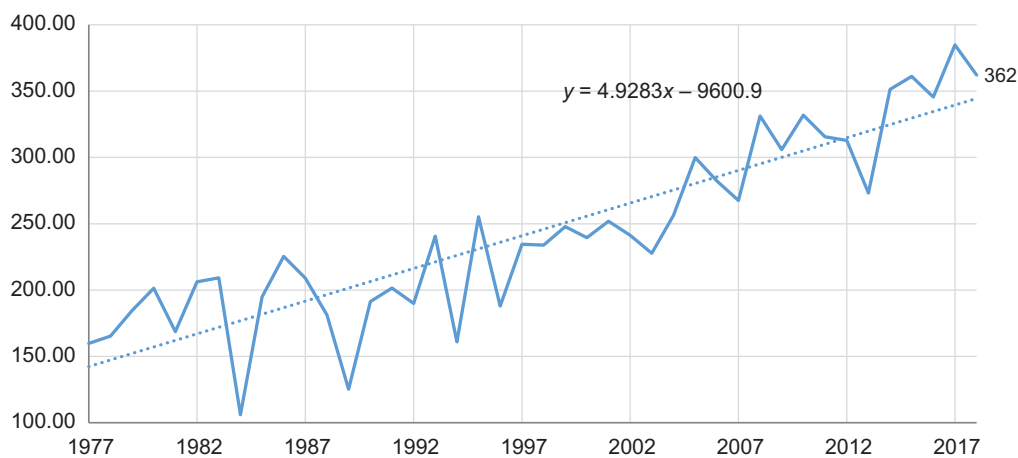


FIG. 4.1 Evolution of USA corn domestic production (millions metric tons per year). (Source: Data from USDA. ERS. Feed Grains Data: Yearbook Tables. July 13th, 2017.)

Ethanol fuel disappearance in the United States has increased in this century more than 10% annually, from about 7,048 million liters in 2001 to about 59,589 million liters in 2016. United States is the leading worldwide producer/consumer and utilizes ground corn or corn starch as main raw material (see Chapter 22). Brazil is the second ethanol producer/consumer, but generates most of this fuel through the conversion of the sugarcane juice. Table 4.3 summarizes the main ethanol producers in the world and clearly indicates that the United States is the major producer. The estimated yearly capacity in 2018 of the ethanol USA industry was of 61.5 billion liters of fuel bioethanol (16,241 million gallons) produced by approximately 200 biorefineries distributed mainly throughout the Corn Belt states. (<http://www.ethanolresponse.com/wp-content/uploads/2018/02/2018-RFA-Ethanol-Industry-Outlook.pdf>).

The market for corn industrial products is also concentrated in few large companies. Global corn wet-milling market includes Tate & Lyle PLC (U.K.), Archer Daniels Midland Company (U.S.), Cargill, Incorporated (U.S.), Ingredion Incorporated (U.S.), Agrana Beteiligungs-AG (Austria), The Roquette Freres (France), Bunge Limited (U.S.), China Agri-Industries Holding Limited (China), Global Bio-Chem Technology Group Company Limited (Hong Kong), and Grain Processing Corporation (U.S.) (Markets and Markets, 2016). Global key players for glucose market are Global Sweeteners Holding, Roquette, Cargill, Ingredion, and ADM (Research and Markets, 2017). Global key players for starch market are Cargill, Ingredion, Tate & Lyle, ADM, Riddhi Siddhi Gluco Biols, and Gulshan Polyols (Globe Newswire, 2017).

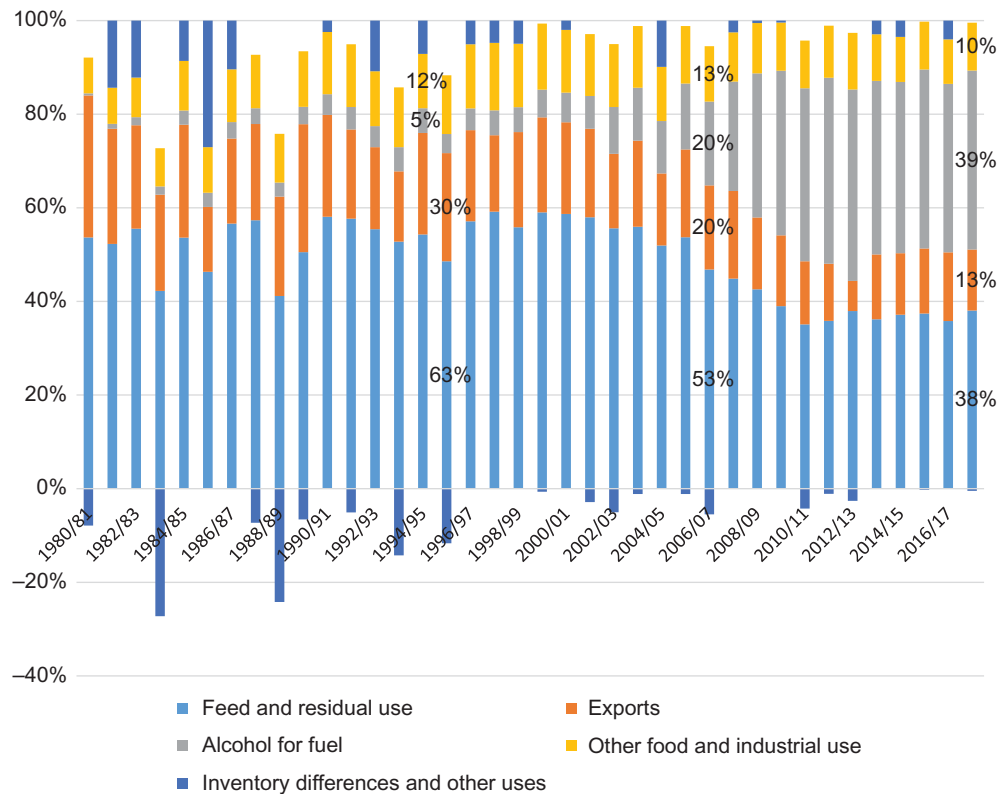


FIG. 4.2 Evolution of USA corn domestic utilization as percentage of production (millions metric tons). (Source: Data from USDA. ERS. Feed Grains Data: Yearbook Tables. July 13th, 2017.)

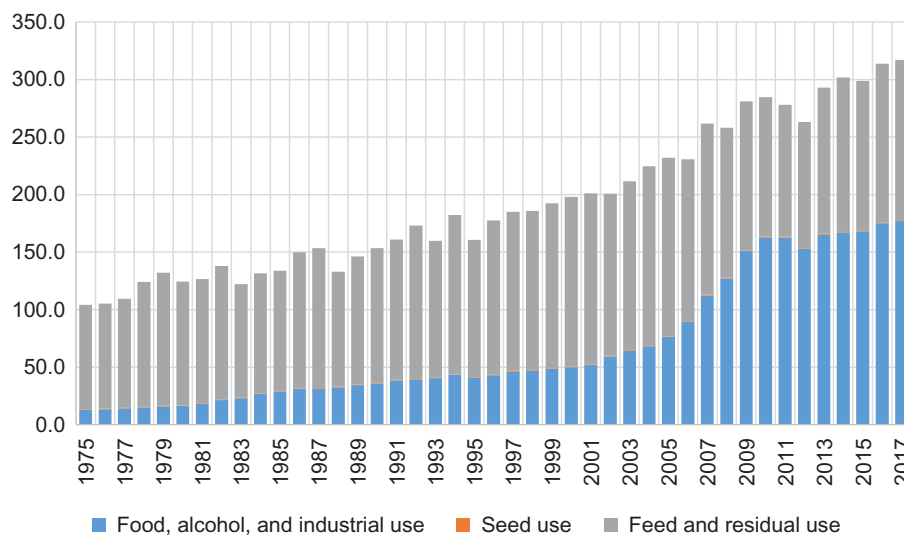


FIG. 4.3 Evolution of USA corn domestic utilization (millions metric tons). (Source: Data from USDA. ERS. Feed Grains Data: Yearbook Tables. July 13th, 2017.)

Breakfast Cereals

Kellogg's was founded in Michigan 1906, by Will Keith Kellogg. He developed and prepared the first "Corn Flakes" to take care of sick patients. Soon his corn flakes were liked by different customers and he built a plant in 1922 to manufacture this breakfast cereal commercially. By 1924, General Mills entered this new industry segment, so today the industry's global



FIG. 4.4 Corn cost of 1000L of ethanol. Corn prices received by farmers. Ethanol is rack prices (wholesale truckload sales or smaller of gasoline where title transfers at a terminal) F.O.B. Omaha. (Source: Own calculation with data from: USDA-ERS-US Bioenergy Statistics. <https://www.ers.usda.gov/data-products/us-bioenergy-statistics/>.)

revenue is more than 45 billion US dollars annually⁵ and is expected to grow 10 more billion by 2022. Besides these two major breakfast cereals producers, other key players operating in the global RTE industry are Pepsi Co (Quaker), Nestlé, Post Holdings, and Cereal Partners Worldwide (Clapp and Fuchs, 2009).

Breakfast cereals are currently manufactured from a complex mix of grains as raw materials, corn being the main one. Grand View Reports⁶: “The market is expected to exhibit a growth rate exceeding 4% CAGR from 2015 to 2022. Consumer awareness towards healthy eating habits is anticipated to drive demand over the forecast period.” One fourth of the industry’s global revenue is generated in United States and half of that comes from two companies: General Mills and Kellogg Co.

According to Euromonitor’s 2015 Global Consumer Trends survey, over half of the consumers in the United Kingdom and the United States spend less than 5 min to prepare breakfast, demanding quick-fix solutions for their morning meal. Yet, cereal manufacturers’ pace with which they tap into this evolving portability and convenience trend differs considerably in these two markets. While in the United Kingdom portability has been gaining pace since 2012 as seen by the rapid rise in snack-portioned cereal sales (<60 g per pack), in the United States snack-portioned cereal sales have faced a noticeable decline, in particular since 2006.

CORN PRICE AND TRENDS

The price of corn incorporates two major elements: Price in organized exchanges, such as the Chicago Board of Trade market, and the Basis. Since the middle of the 19th century, organized exchanges came into being for operating commodities. Chicago saw the birth of some of those organized exchanges. Examples of these markets are the Chicago Board of Trade (CBOT) and the Chicago Mercantile Exchange (CME). CBOT was initiated in 1848 as spot market, but by 1865 operated the first derivative contract (futures). Since then, derivative markets have evolved and offer a wide range of tools that allow hedgers to manage price risks. As of today, in addition to future contracts, organized commodities exchanges operate Options Call (right with no obligation to buy in the future at certain strike price) and Options Puts (right with no obligation to sell in the future at certain strike price). In these markets participate sellers and buyers, hedgers, and speculators. All of them are welcome to participate because, among all participants, the liquidity improves and the price adjusts faster to all relevant information. It is important for markets to work well; that one single economic agent must not have the possibility to influence the market price. Corn market works well, while others, such as dry milk, are more concentrated and do not work well because they do not have enough number of participants.

5. Mordor Intelligence. Taken from: Breakfast Cereal Manufacturing. Industry Profile 9.18.2017. First Research, a Dun & Bradstreet company.

6. <http://www.grandviewresearch.com/industry-analysis/breakfast-cereals-market> as November 13th, 2017.

Analyzing the intraday prices (CBoT Corn Composite Commodity Future “Cc1” | Price History | Thomson Reuters Eikon) of the following Month future contract since March 2008–March 2018, one can find that the intraday price variation (High-Low) is 2.52% of the closing price with a standard deviation of 1.45%. This volatility happens with an average of 1.269 million open interest contracts, 127 metric tons each contract (5000 bushels each). Those numbers imply that the next month future contract in CBOT exchange negotiates sellers’ and buyers’ positions for 161 million tons of corn. The intraday volatility did not show difference among weekdays and averages were 2.60%, 2.53%, 2.46%, 2.49%, and 2.51% for Mondays, Tuesdays, Wednesdays, Thursdays, and Fridays, respectively.

Prices in future markets are in equilibrium with spot market prices. If spot price goes up, future price must react in similar direction and magnitude, neutralizing the cost of carry and the convenience yield. This relation offers the possibility to hedge price risks taking a position (Long—buy the future contract; Short—sell a future contract) in future markets. Future markets ensure transaction compliance because they have a clearing house that daily mark to market positions of participants and each participant must have a debit margin account.

To have a position in future markets, one must open an account and one only needs to deposit a margin account, and there is no need for the whole future contract amount. Margin covers more than the maximum daily price variation and margin balance can go up or down daily, depending on the daily gain or loss in the taken position. Commission fees in derivative markets are very low and these markets have shown a significant growth.

While spot markets can manage the one single day transactions, future markets operate typically monthly contract for the following years and not all positions are intended to end in a delivery. This effect makes future markets bigger than spot markets. Future markets offer easy buying and easy selling a market position. Offering risk management tools, future markets help producers and economic agent to raise capital. At expiration, future price meets spot price in ground zero⁷ as are for authorized warehouses, shipping stations, or authorized ports in some districts of the Chicago region for the Chicago market. The exchange rulebook defines the price for certificates of deposit of maize stored in other nearby Chicago districts, and it may be 0.79–6.7 dollars more per ton than exchange price (2–17 cents more per bushel).

The second element of price is the Basis, which is the difference between local spot price and the price in one specific future contract. Basis prices are less volatile and more predictable than future prices. Basis prices may be below or above zero. As example, it may be below zero at harvest season in a specific region far away from the corn’s customer. Economic agents say that “basis weakens” if basis prices increase because spot price drops more than future price. Additionally, the “basis is strengthened” if the prices of the basis fall because spot price increases more than future price. At the end, the basis price is a negotiation between a particular seller and buyer.

Freight cost is an important element in basis price, but it is not the only element. Other elements as local offer and demand, local inventories and storage capacity, local milling operation versus capacity, local logistics, seasonality of utilization, and purchase power of local communities impact the basis price.

Basis prices are also influenced by substitutes and complementary products. For instance, local harvest of sorghum may influence corn’s basis price because it is the typical substitute for feed use. Basis prices are furthermore influenced by lot size and transportation cost. The cost of carry (storage, handling, financial, insurance, and loss costs) and weather forecasts influence basis prices too. Incoterms such as *Free On Board* (FOB) or *Cost, Insurance and Freight* (CIF) define the specific moment of the transaction and also influence the basis price, as local forecasted harvest does.

Economic agents say that local markets are “with carries” if forward prices are higher than spot prices; otherwise the used terminology to describe it is “inverse market”. This last situation may happen if, in the near term, the delivery is over last year’s storage grain while forward will deliver new future harvests.

Despite the corn price in real terms has been coming down systematically (Fig. 4.5), the higher yields compensate the producer’s revenue.

CORN PRODUCTION

Global Production

On a yearly basis, as Table 4.4 shows, more than 1 billion metric tons of corn are produced making this crop the most relevant grain in terms of volume. Two countries produce more than half of the worldwide corn supply. The United States is the leading producer with almost 35% of the total production followed by China with nearly 21%. The big difference between these two countries is that corn is domestically used by more than 1.4 billion Chinese people, whereas 13% of the USA corn is exported to many countries throughout the globe.

7. Ground zero means all nearby Chicago market’s authorized storage facility that generates market’s authorized deposit certificate.

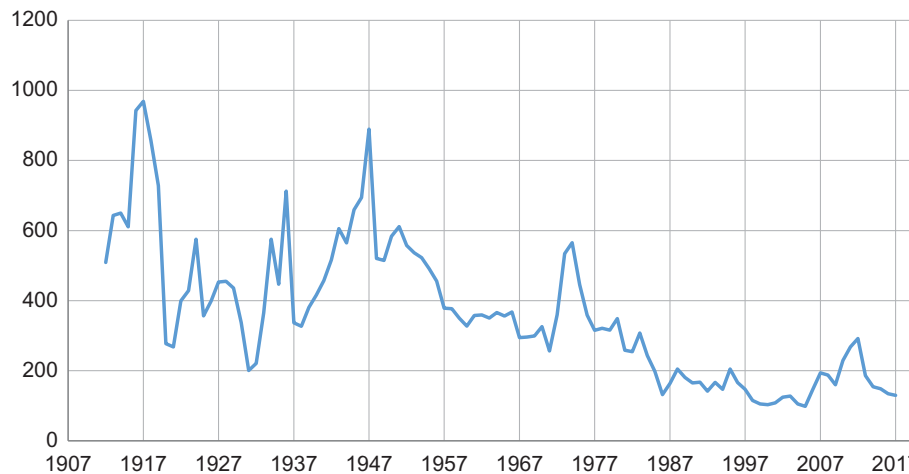


FIG. 4.5 US Real corn prices adjusted to January 2018 by Consumer Price Index (USD/ton). (Source: From USDA. ERS. Feed Grains Data: Yearbook Tables. July 13th, 2017 and Consumer price index at <http://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008/>.)

TABLE 4.4 World Corn Production (1000 Metric Tons)

	2013/14	2014/15	2015/16	2016/17	2017/18	2017/18 (%)
United States	351,272	361,091	345,506	384,778	362,094	34.9%
China	218,489	215,646	224,632	219,554	215,000	20.7%
Brazil	80,000	85,000	67,000	97,000	95,000	9.2%
European Union	64,931	75,734	58,731	60,711	61,600	5.9%
Argentina	26,000	29,750	29,000	41,000	40,000	3.9%
Ukraine	30,900	28,450	23,333	28,000	28,500	2.7%
India	24,259	24,170	22,570	26,000	25,000	2.4%
Mexico	22,880	25,480	25,971	27,400	25,000	2.4%
Russia	11,635	11,325	13,168	15,305	16,000	1.5%
Canada	14,194	11,487	13,559	13,200	14,400	1.4%
South Africa	14,925	10,629	8214	16,400	12,500	1.2%
Indonesia	9100	9000	10,500	10,900	11,350	1.1%
Philippines	7532	7671	6970	8110	8300	0.8%
Serbia	5900	7700	6000	7600	7000	0.7%
Nigeria	7700	7515	7000	7200	6900	0.7%
Ethiopia	6492	7235	6800	6350	6700	0.6%
Others	98,484	101,532	99,853	99,285	101,554	9.8%
World Total	994,693	1,019,415	968,807	1,068,793	1,036,898	100.0%

Source: Foreign Agricultural Service/USDA. Office of Global Analysis. July 2017. <https://apps.fas.usda.gov/psdonline/circulars/grain-corn-coarsegrains.pdf>.

Corn production in the United States grows at a rate of almost 5 million tons per year, as shown in Fig. 4.1. Table 4.2 depicts that the production of fuel bioethanol has absorbed a large part of this production growth, reaching levels of almost 40% of the domestic corn supply. In the United States, farmers can clean, dry, and store some corn of their own harvest. Leath (2003) reports that farmers in United States own more than half of the United States grain storage facilities (on-farm

and commercial). Farmers trade corn to two types of collectors or grain elevators and dealers: private and cooperatives. In order to economize in transaction costs, both institutions attempt to have multimodal⁸ transshipment facilities.

On the other hand, China consumes more corn compared to the domestically produced. Meng et al. (2013) report that corn is the second-largest food crop in China and accounts for one third of the total cereal production. They report that the country's average corn yield has improved from 1 metric ton per hectare in 1960 to 5 tons in 2010. They analyzed the crop's potential and, in general, concluded that the actual yield of this corn crop is about half of the potential yield and the improvement in production will play a key role to ensure national food security.

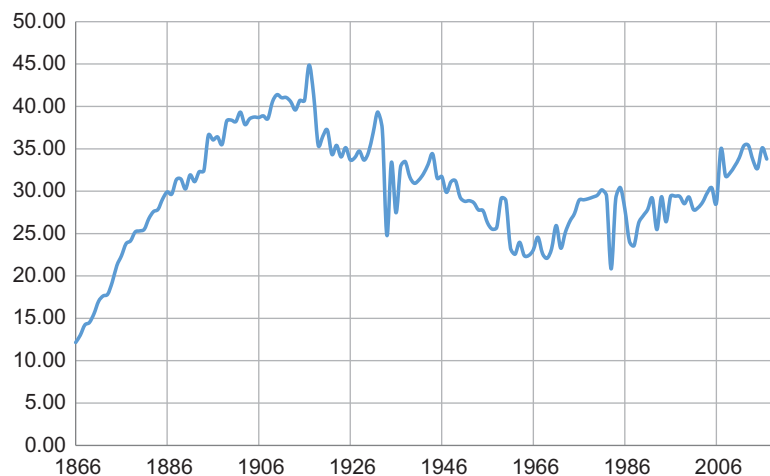
Productivity, Key Elements for Competitiveness, and Production Costs

It is well-known that supply growth responds to productivity improvement. As Fig. 4.6 shows, the United States annually plants about 30 million hectares of corn. The land competes with alternate uses and it is not very easy to increase production by planting more land. Therefore, the only way to further increase production is by improving yields (Fig. 4.7). In fact, USA corn productivity has increased constantly during the past 80 years and this positive trend is expected to continue. Corn yield increase is the main driver of the 5 million tons of the annual production growth in United States.

Nielsen (2012) details satisfactorily the improvement in corn productivity in the United States quoting that: “during the early years of the 20th century, researchers at several universities worked on developing a genetic ‘advancement’ that would eventually lead to the first significant and sustained improvement in maize yields. Farmers began to adopt hybrid technology, seed corn that not only exhibited dramatically higher yield potential but also significantly better tolerance to stress. The advanced farming systems and technologies responsible for this amazing shift in maize productivity of about 120 kilograms/hectare/year were a combination of the adoption of further genetic improvements (single-cross hybrids), inorganic nitrogen fertilizers (anhydrous ammonia, urea, etc.), chemical pesticides (2,4-D, etc.), and agricultural mechanization (tractors and other self-propelled equipment) complemented with GPS, precision agriculture, remote sensors, and variable rate (VR) seed and fertilization technologies.”

The same author further details that the national maize yield in the United States over the past 5 years (2007–2011) averaged 9.7 tons/ha. The average grain yield for the two largest maize producing states in the United States (Iowa and Illinois) for the same 5-year period was 10.7 tons/ha. It is expected for both averages to maintain the growth rate of 120 kg/ha/year. Fig. 4.7 shows that USA national average exceeded 10 tons/ha. In recent years, the increasing availability and affordability of precision agriculture such as sub-inch (cm) accuracy in GPS receiver technologies has contributed to growers' interest in auto-navigation and auto-control technologies. He believes that it is fair to say that none of today's precision agriculture auto-nav or autocontrol technologies represents a “quantum leap” in maize productivity, but rather they offer the potential to reduce production costs through more accurate placement of crop inputs.

FIG. 4.6 USA corn harvested land (millions hectares).
(Source: From USDA. ERS. Feed Grains Data: Yearbook Tables. July 13th, 2017.)



8. Multimodal: To offer the possibility to switch among different transportation modes.

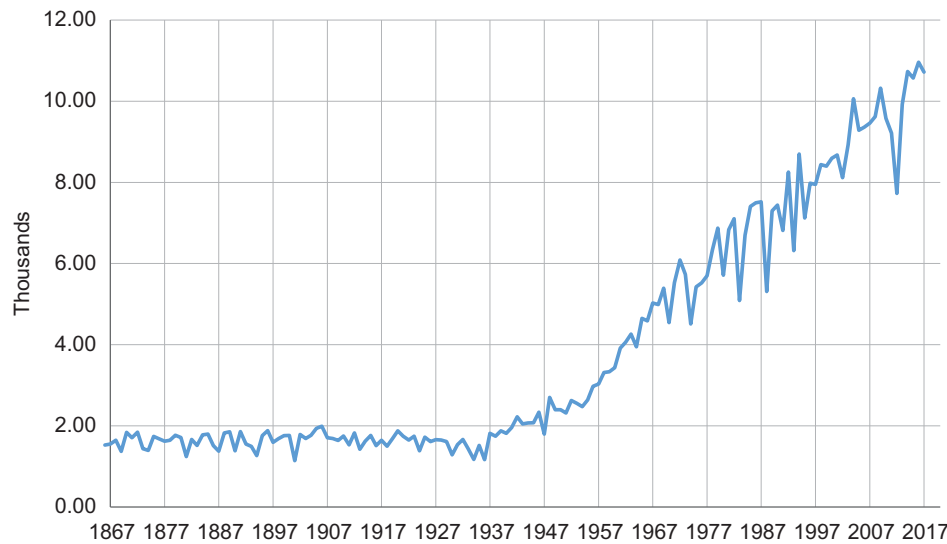


FIG. 4.7 Evolution of the corn yield in the United States (kg per hectare). (Source: Made with data from the USDA. ERS. Feed Grains Data: Yearbook Tables. July 13th, 2017.)

World maize production evolves into more capital-intensive systems, particularly intensive in seed, soil fertility/plant nutrition, and machinery and equipment. The central issue is to reduce the limiting factor such that the genetic potential can be fully expressed. This intensity impacts a constant increase in yield per hectare in worldwide corn harvest.

Related to seed, biotechnology impacts corn supply, improving the genes (as if it were software) inside seeds. Two traditional grower's technical problems in the production of corn are pests and weeds. In corn seed, the technology has evolved to GMOs in two areas, insect-resistant and herbicide-resistant (see Chapter 3). The *Bacillus thuringiensis* (Bt) is a bacterium that occurs naturally in the soil and produces proteins that kill certain insects. It was first discovered as the cause of death of silkworms in 1901 by the Japanese biologist, Shigetane Ishiwatari. In the German town Thuringia, Ernst Berliner isolated the bacteria in 1911 and rediscovered Bt. The main insecticidal activity against lepidopteran (moth) insects in larvae phase was due to the parasporal crystal. Farmers started to use Bt as a pesticide in 1920 and commercial Bt pesticide begun in France in 1938. By 1961, Bt was registered as a pesticide to the EPA. With the advancement in biotechnology, it soon was possible to move the gene that encodes the toxic crystals into a plant. Corn was the first genetically engineered crop and was registered with the EPA in 1995. In order to prevent plague resistance to Bt, growers must plant a non-Bt crop as refuge for the insects. Another GMO development that arrived to seed market is herbicide tolerance (HT). Roundup-Ready Corn is resistant to a common herbicide called glyphosate, with brand Round Up and patented by Monsanto; patent now expired. USDA-ERS 2017 reports that grower's expense in GMO seed is about one third of grower's supply costs, but investment in good seed pays back (USDA-ERS, 2017b, US corn production costs).

Soil fertilization is the application of nutrient supplements to make available nutrients to the plant. Bundy (1998) reports: "Profitable corn production requires an adequate soil fertility program. Insufficient nutrients will lower yields; excess nutrients will lower profit margins and may damage the environment through nutrient runoff and leaching. Corn must receive adequate amounts of nutrients to fully realize yield. Corn uses substantial amounts of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) and relatively small amounts of secondary nutrients and micronutrients." USDA-ERS (2017b) reports that grower's expenses in corn nutrition are about 40% of the supply costs.

Related to machinery and equipment, world's corn growers increasingly apply precision agricultural practices like high precision positioning systems (error less than two centimeters), remote sensors and automated actuators, automated steering, geo-mapping, communication, drones, or variable rate technologies (VRT) to perfect different crop activities. This requires capital expenditure and capital commitment.

United States is the main corn producer and exporter driven by proper agricultural policies in the "Farm Bill," which defines agriculture public policies for 4–5 years. This offers growers, lenders, and agriculture stakeholders certainty about grower's cash flows and improves the quality of food and the conservation of resources. This certainty favors financing and capital expenditure and investments aimed toward the improvement of productivity and reducing costs. Other countries such as Mexico define one single year agriculture policies and the regional impact on productivity and costs is not clear, even when the fiscal costs of the policy could be similar to the United States' farm bill.

CORN GLOBAL TRADE

About 14% of the annual corn supply participate in global trade and about one third of the corn global trade comes from USA exports. Table 4.5 and Figs. 4.8–4.11 show that United States, Brazil, Ukraine, and Argentina are net corn exporters and they together account for 70% of the worldwide corn exports estimated in 150 million tons. Japan, Mexico, South Korea, Vietnam, Spain, and Iran account for the top 42% of the corn imports (Table 4.6). China is one of the top producer countries, but its demand is larger than its production, so this country normally imports corn to fulfill the deficit.

The largest demand of the corn in the global trade is for production of feedstuffs which are transformed into relevant animal proteins for direct human use. The Economic Research Service (ERS) reports: “*Corn is by far the largest component of global coarse-grain trade, accounting for about three-quarters of total volume in recent years (coarse grains make up a common trade category that includes corn, sorghum, barley, oats, and rye). Most of the corn that is traded is used for feed; smaller amounts are traded for industrial and food uses. Processed-corn products and byproducts—including corn meal,*

TABLE 4.5 Worldwide Corn Exports (Metric Tons)

País	2012	2013	2014	2015	2016	%
World	120,853,206	124,635,912	127,298,515	146,297,635		
United States	31,472,438	24,079,857	35,770,153	44,654,593	56,219,661	31%
Brazil	19,801,938	26,624,888	20,654,640	28,923,951	21,873,310	20%
Ukraine	15,630,888	16,729,467	17,556,531	19,048,697		13%
Argentina	17,855,373	20,069,646	15,895,181	16,736,636	24,504,610	11%
France	6,294,289	6,284,770	5,847,523	7,192,564	5,439,440	5%
Rumania	2,272,649	3,233,351	3,708,953	5,125,274	3,439,251	4%
Other	27,525,631	27,613,933	27,865,534	24,615,920		17%

Source: Statista > <https://www.statista.com/statistics/254299/top-global-corn-exporters/>.

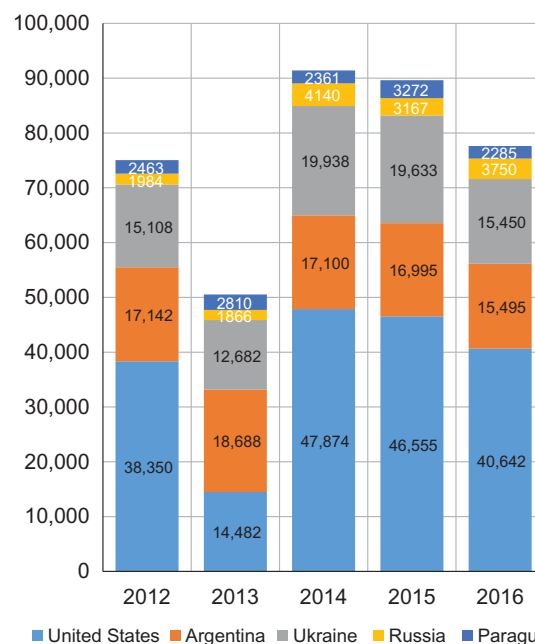


FIG. 4.8 Corn trade balance of five net exporters' countries (1000 metric tons). (Source: From BMI Research, 2017. Business Monitor International Ltd. Export date. September 19th 2017.)

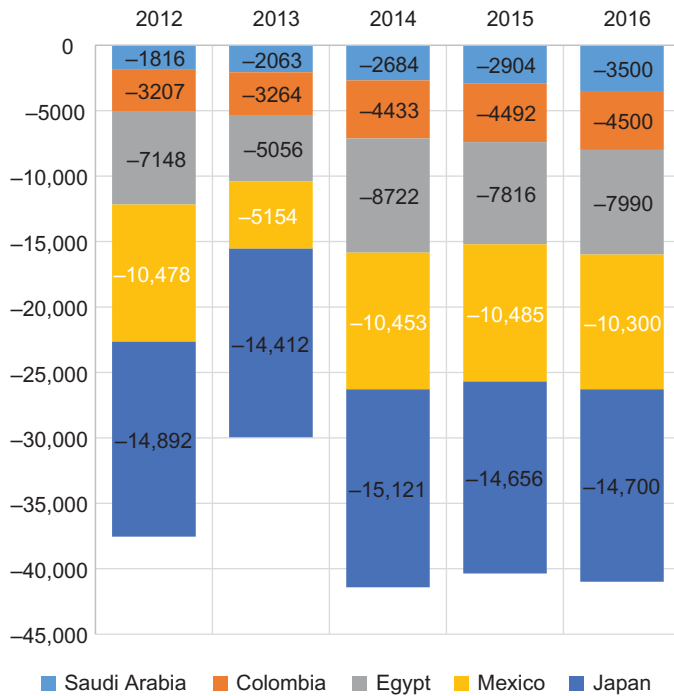


FIG. 4.9 Corn trade balance of five net importer's countries (1000 metric tons). (Source: Made with data from the BMI Research. Copyright © 2017 Business Monitor International Ltd. Export date. September 19th 2017.)

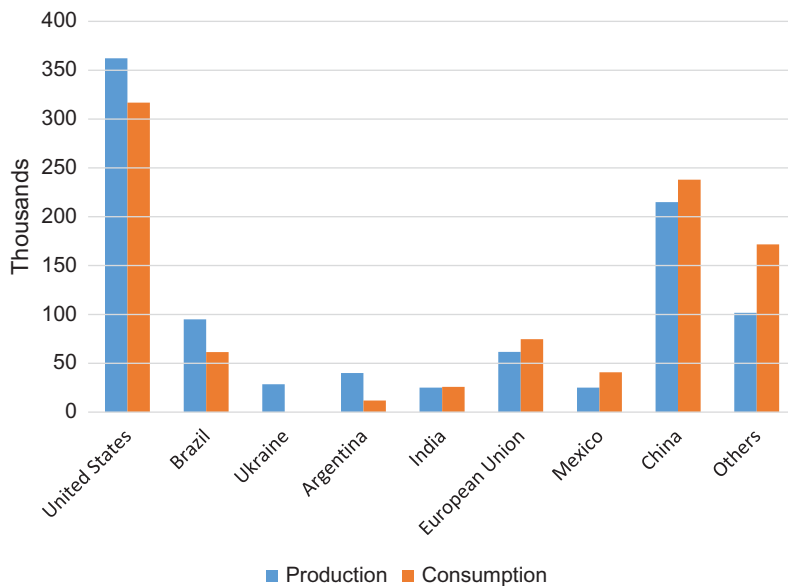
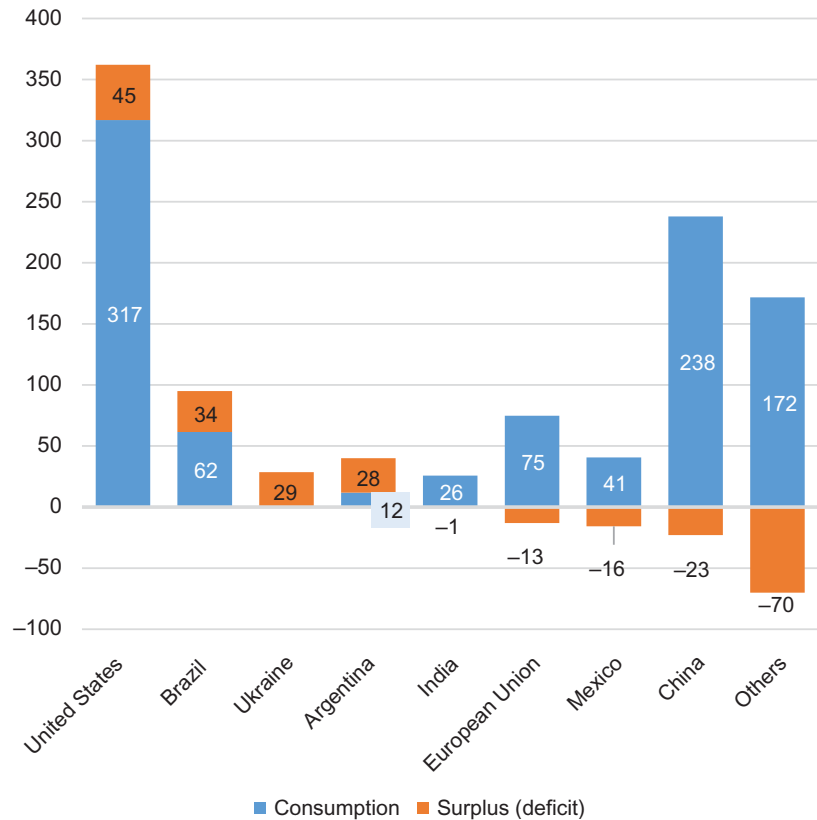


FIG. 4.10 Corn production and consumption of several countries (thousand metric tons)". (Source: From BMI Research, 2017. Business Monitor International Ltd. Export date. September 19th 2017.)

flour, sweeteners, and corn gluten feed—are also traded.” ERS also reports that China’s participation in global trade is hard to forecast citing: “China has been a significant source of uncertainty in world corn trade, swinging from the second-largest exporter in some years to an importer of large quantities in other years. China’s corn exports are largely a function of Government export subsidies and tax rebates because corn prices in China are mostly higher than those in the world market. Large corn stocks are expensive for the government to maintain, and Chinese corn trade policy fluctuates with little relationship/vessel to the country’s production, making China’s corn trade difficult to predict.”

Few large companies concentrate corn market’s transactions in global trade. The most relevant are Cargill and Archer Daniels Midland Company (ADM) in the United States, the Bunge Group founded in Amsterdam but expanded from South America (Argentina and Brazil), Louis Dreyfus in France (All together referenced as ABCD firms), Nidera in the Netherlands, Noble in Hong-Kong, and ZenNoh in Japan (Clapp, 2012; Clapp and Fuchs, 2009).

FIG. 4.11 Estimated 2017–2018 national corn use and trade balance of several countries (thousand metric tons). (Source: From BMI Research, 2017. *Business Monitor International Ltd. Export date. September 19th 2017.*)



MARKETS AND EXCHANGES

Markets are usually physical spaces where suppliers and buyers of a certain product can meet. Markets ease transactions (exchange of products and payment), help in price discovery informing producers and consumers about prices, and are logistically convenient. Marketing involves physical facilities for cleaning, drying, conditioning, storing, blending, and transporting corn and its byproducts.

A market is said to be efficient when its price reflects all available information. Not all markets are efficient and not all markets labeled as efficient remain so always. Grain markets were first developed near production zones and multimodal logistics facilities like Doncaster-Leeds-Sheffield in England, Chicago IL in the United States, or the *Bolsa de Cereales* in Argentina (Holland, 2015; Editors of *Encyclopedia Britannica*, 2016).

Markets may be used to exchange products directly in liquid or spot markets or to commit now to a future exchange. The first market is called cash or spot market and the second is named future market.

In current times, products need not be physically present in the market. Spot market exchange deposit certificates from authorized warehouses that guarantee the quality and quantity of product found therein. These markets can vary depending on: distance from the base market (ground zero); harvest season timing; logistic facilities like railroad access or access with efficiencies to utilization centers; availability to global and local inventories; and efficiencies in the cost-of-carry and convenience yield. The local reference price reflects these differences related to the exchange spot market price—this amount is known as “basis.” As were explained previously, Basis is the difference between the futures price and your local cash price. Based on arbitrage assumption that considers relevant price issues, spot and future prices converge at future maturity (Hull, 2000).

Corn markets developed as economic centers, and as such, soon evolved into physical enablers of the corn trade.

TRANSPORT AND LOGISTIC

Transportation is a key factor in corn marketing since the prices paid to producers or those paid by the consumer are closely linked to the prices of central markets, adjusting their value to the cost of freight. Transportation takes corn from places where the quantity offered is greater than the one demanded to places where the quantity demanded is larger.

TABLE 4.6 Worldwide Corn Imports (Metric Tons)

País	2012	2013	2014	2015	2016	%
World	NA	127,402,192	131,218,664	136,548,085	NA	
Japan	14,890,840	14,400,941	15,034,845	14,708,191	15,341,777	10.8%
México	9,515,074	7,153,033	10,407,011	12,145,301	14,105,991	8.9%
Korea, South	8,220,237	8,722,682	10,221,214	10,349,626	9,789,907	7.6%
Vietnam	1,615,503	2,186,492	4,764,031	7,622,377		5.6%
Spain	6,064,361	5,524,270	6,258,841	6,960,437	5,994,531	5.1%
Iran	4,686,260	4,016,605	6,184,288	5,335,355		3.9%
Netherland	4,163,277	4,649,565	5,448,643	4,963,366	4,205,216	3.6%
China	5,207,111	3,264,886	2,598,461	4,730,035	3,166,588	3.5%
Colombia	3,200,336	3,635,279	3,961,571	4,717,637	4,586,084	3.5%
Argelia	3,041,015	3,218,998	4,108,043	4,417,613		3.2%
Taipei	4,362,092	4,062,945	4,211,968	4,210,973	4,222,165	3.1%
Italia	2,653,853	3,991,311	4,609,398	3,743,421	4,466,655	2.7%
Malaysia	3,031,156	3,389,079	3,822,338	3,577,736	3,599,445	2.6%
Indonesia	1,692,994	3,191,045	3,253,619	3,267,694		2.4%
Perú	1,847,208	2,020,923	2,331,865	2,684,178	3,040,358	2.0%
Germany	2,215,451	2,128,534	3,072,442	2,506,659	2,301,903	1.8%
Saudi Arabia	1,911,613	2,105,798	2,568,014	2,318,316		1.7%
Morocco	2,025,926	1,765,313	2,094,218	2,081,346		1.5%
United Kingdom	1,247,697	2,060,594	2,209,435	1,986,627	1,657,884	1.5%
Venezuela	2,273,222	2,059,520	2,436,459	1,847,123		1.4%
Other		43,854,379	31,621,960	32,374,074		23.7%

Source: Statista > <https://www.statista.com/statistics/254299/top-global-corn-exporters/>.

As stated previously, United States is the world's leading producer and exporter and its corn industry and market infrastructure is better developed. In this country, the corn is transported by heavy trucks, railroad, and barges or ships/vessels. In export markets, it is generally transported by ship/vessel except to Mexico, where it's normally transported by railways. [USDA-AMS-GSR \(2018\)](#) reports that Mexico imports roughly 80% of U.S. grain by rail and 20% by ocean vessel.

Commercially corn is transported in bulk at environmental conditions, and therefore, does not require additional controlled environments (i.e., refrigeration, frozen storage, etc.) like other agricultural products such as fruits, vegetables, meats, and dairy products. However, corn requires preventive measurements to protect it from pests and exposure to rain/moisture.

Among the different modes of transport, the most flexible system is by heavy trucks which is commonly utilized to move grains in relatively short distances. It is still the first transport regularly used to move corn from farms to grain elevators or receiving plants. Harvested corn from the producer is usually first received by a local plant with the aim of reducing its moisture to safe levels (around 14% moisture content (MC)) and to remove foreign material or dockage (see [Chapter 7](#)). After these operations, the corn is sent to intermodal facilities for customers. In export countries like Brazil, 63% of soybean and corn is moved through heavy truck transport systems ([Meade et al., 2016](#)).

The Texas A&M transportation Institute performs transportation research studies about every 5 years ([Kruse et al., 2017](#)). The study compares alternate transportation modes within the United States that count with navigable rivers. This report compares cargo capacity, congestion, emissions, energy efficiency, safety issues, and infrastructure impacts.

TABLE 4.7 Estimated Carrying Capacities of Dry and Liquid Cargo Barges, Railcars, and Semitractor/Trailers

	Modal Freight	Unit Standard Cargo Capacity	Single Barge Equivalent
	Highway—Truck Trailer	25 tons	70.0 ×
	Rail—Bulk Car	110 tons	15.9 ×
	Barge—Dry Bulk	1750 tons	1.0 ×
	Barge—Liquid Bulk	27,500 bbl	

Source: From Kruse, C.J., Warner, J.E., Olson, L.E., 2017. A modal comparison of domestic freight transportation effects on the general public: 2001–2014, in National Waterways Foundation, Center for Ports and Waterways, Texas A&M Transportation Institute, The Texas A&M University System, College Station, pp. 1–63.

Table 4.7 compares carrying capacity among alternate transportation modes. With the Kruse et al. (2017) data, Welshans (2017) states that a normal single 15-barge single river tow is capable of carrying the equivalent to 1050 trucks or 216 railcars pulled by six locomotives. The same study indicates that the estimated distance required to move one dry ton with a single gallon (3.70 L) of fuel are 1041 km (647 miles), 767 km (477 miles), and 233.4 km (145 miles) in barge, train, and truck, respectively.

As previously stated, heavy truck is the most flexible transportation mode. For large volumes and long distances on land, railroad is the dominant means of transportation. Since the 1990s, there have been several changes in the way of operating the railroads. These changes have been performed in order to increase efficiency and profitability. The main modification highlights the utilization of shuttle trains consisting of 75–116 bulk hoppers moved by three or four locomotives, which are assigned depending on the power demanded by the route. Each hopper can contain +110 metric tons of corn and each train can move between 7150 and 11,000 metric tons. Logistic wise, each shuttle train has a single origin and a single destination and is committed to loading and unloading in less than 15 h at each end. Shuttle trains have route priority over ordinary trains and only stops to change crew and refuel diesel. Needless to say, these improvements translate into lower transportation costs (Anonymous, 2018).

Another relevant change in the 1990s in the rail road industry was the conditioning of the rail to be able to transport heavier hoppers that went from 121.6 metric tons (268 thousand pounds) to 130 metric tons (286 thousand pounds) each. This change brought the design of larger capacity hoppers ($>153 \text{ m}^3$ or 5400 cubic feet) with a lower tare and a shorter length (Anonymous, 2018).

The main railroad USA companies auction lots of shuttle trains, generally with more than 108 hopper cars each with the commitment to use for 1 year under the established conditions. If the winner of the auction does not use the train, there is a secondary market where the right to use one or more train trips in exchange for a payment can be negotiated. There is a balance between supply and demand in this secondary market. There are periods when in the best interest of the owner there is the right to pay other parties for using the hoppers instead of paying the penalties to the railroad company.

Barges (Fig. 4.12A–C) are used to move the corn from grain elevators at shore through navigable rivers to the export seaports. This transport mode generally is very economical under normal conditions. Barges are common transportation mode from Middle East to New Orleans Louisiana or Mobile Alabama ports through Mississippi river. From Middle East to Pacific ports, the dominant mode is shuttle trains.

For export markets, ships/vessels are the dominant transportation mode. There is a tendency to increase the size of these vessels, so new ships/vessels are designed to have a capacity to bulk transport up to 70 thousand metric tons. The keel of these large ships/vessels is more than 12.2 m (40 ft) deep, and therefore, to maneuver within a port, they require enough depth and special port facilities equipped with long docks capable of receiving these large ships/vessels with a length of more than 225 m.

The industry dedicated to bulk transportation is influenced by supply and demand as well as the efficiencies in its activities and operations. This industry requires precision in the intrinsic physical and chemical characteristics of the corn in order to prevent deterioration while transportation. Prices and efficiency of vessel transportation are influenced by vessel traffic in certain ports or routes. This industry also requires operating with specialized equipment and bulk intermodal storage facilities. If the price of corn changes, it is possible that the competitiveness of the industry to transport corn is altered.

It is important to highlight that there are contracts and regulations that govern transactions between the provider of the shipping services and the user. Along with the transported merchandise, documents such as invoice, bill of loading,

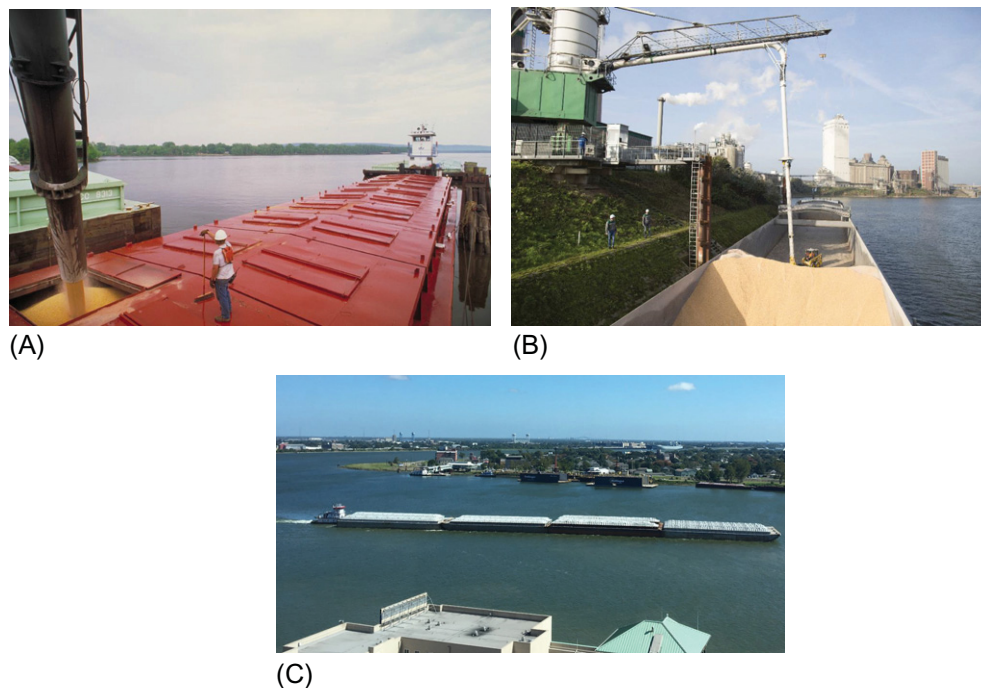


FIG. 4.12 (A) Barge commonly used to transport corn. (B) Barge commonly used to transport corn. (C) Eight-barge navigating the Mississippi river (front of New Orleans) which can move 1.75 thousand metric tons of grain per barge. ((A) Photograph courtesy of Cargill. CARGILL; (B) Courtesy of Cargill. CARGILL; (C) Photograph taken by the senior author. May not be reproduced without written permission.)

phytosanitary certificate, origin certificate, weight certificate, and quality certificate must be generated and attached. The contracts establish incoterms, responsibilities and rights in case of delays, costs for both loading and unloading, payment of insurance in transit, losses during transportation, etc.

CONCLUSIONS

Corn is currently and will continue to be one of the most important grains for humankind because it is highly efficient in terms of yield per unit of land and used for production of many human food, the basis for the production of animal feed-stuffs, and has many industrial uses including production of fuel bioethanol. The future of corn is bright and its demand will continue to increase about twice the growth of the population that is expected to reach at least 9 billion people by year 2050.

Corn accounts for more than half of the GDP of specialized regions in producer's countries. Along all the value chain, efficiency and productivity are must to survive. Producer's suppliers must offer value propositions, especially in terms of improved seeds, fertilizers, and machineries. Producers require to take advantage of scale economies, technologies, and capital intensity. Because the corn commodity is relatively inexpensive, the logistic costs may be relevant to specific market's price and local markets may offer a cost advantage to local producers. Grain elevators and brokers must operate with efficiency and productivity and those with multimodal facilities will perform better compared to traditional local heavy truck grain elevators. Transportation will keep looking for efficiency and productivity improvements. The expanding corn industry will keep looking for added value products by transforming or processing whole, dry-milled, or wet-milled components into improved products to consumers. In general, corn use for feed is quite stable in different countries with intensive livestock production systems, but industrialized products such as starch, sweeteners, fuel ethanol, corn-based processed food, and nixtamalized products offer ample space for demand growth.

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