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Brazil's Ethanol Industry: Looking Forward

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Contents

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Abstract

Brazil is a major supplier of ethanol to the world market, the result of its natural advantage in producing sugarcane, productivity increases, and policies stimulating the supply of feedstock and of sugar-based ethanol. Global demand for ethanol and other biobased fuels is expected to grow in response to mandates for increased use of renewable fuels around the world. Brazil will be well positioned to fill the growing world demand for ethanol. However, Brazil's ability to supply the export market depends on its domestic ethanol use mandate, world sugar and oil prices, the currency exchange rate, and the infrastructure to move ethanol to ports. Brazil is challenged with sustaining production growth in the ethanol sector so as to meet increasing domestic demand and, at the same time, maintain its position as a major supplier of ethanol to world markets that are growing rapidly in response to their own ambitious targets for renewable energy use.

Keywords: Brazil, ethanol supply chain, sugarcane, sugar, agricultural policies, subsidized credit allocations, challenges for the ethanol industry, future perspectives, domestic and global ethanol demand

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Introduction

Ethanol—a fuel produced from agricultural and other organic materials (biomass)—is considered to be one of the best alternatives to petroleum for transportation fuel, as increased ethanol use reduces the levels of carbon monoxide and carbon dioxide (CO2) emissions relative to fossil fuel use. Tropical sugarcane is also cited as the most efficient ethanol feedstock in terms of greenhouse gas (GHG) emissions avoided per hectare cropped per year (1 hectare = 2.47 acres). A recent study found that the use of sugarcane ethanol in Brazil resulted in a reduction of 600 million tons in CO2 emissions since 1975, an amount equivalent to about 7 percent of Brazil's total CO2 emissions from the consumption of energy over the same period (UNICA, 2010a; EIA 2010a). Moreover, the Environmental Protection Agency (EPA) deems sugarcane ethanol an advanced biofuel that reduces GHG emissions by 61 percent, compared with gasoline GHG emissions (EPA, 2010). The ethanol energy yield ratio, which relates the energy output of ethanol to the fossil energy input used in its production, is often cited as evidence of the benefits of ethanol derived from biomass. The energy yield ratio of sugarcane-based ethanol is 4 to 6 times greater than the energy yield ratio of corn-based ethanol (von Blottnitz and Curran, 2006; Macedo and Seabra, 2008; Shapouri et al., 2010). Because of these outcomes, many countries have implemented energy policies that call for increased ethanol use in their transportation sectors.

Ethanol is used in blends with gasoline and in dedicated 100-percent ethanol-fueled vehicles. Ethanol is produced from feedstock containing natural sugars or starch that can be readily converted to sugar. Feedstock used to produce ethanol includes sugarcane, corn, sugar beets, and wheat. Recent technological advances have identified other renewable energy products, including cellulose ethanol, which is derived from cellulosic feedstock crops such as switchgrass, mixed-species grass, restored prairie, miscanthus, poplar, sugarcane bagasse, straw, and other plant wastes (James et al., 2009). Ethanol produced in Brazil is derived from sugarcane. Brazil's ethanol production in 2010 (31 billion liters) (1 liter = 0.26 gallons) was equivalent to 38 percent of worldwide ethanol production, second only to the United States (49 billion liters), the world's leading producer since 2006 (EIA, 2010b).

In Brazil, two types of ethanol are produced—anhydrous (pure ethanol) and hydrous. Anhydrous ethanol is typically blended up to 10 percent with gasoline for use in unmodified engines, to a maximum of 25 percent in Brazil—with modifications to the engine calibration system to detect the higher oxygen of ethanol blends (UNICA, 2009). Hydrous ethanol (E100) is used in 100-percent ethanol-fueled vehicles and the newer "flex-fuel" vehicles, which are powered by gasoline (E25) and ethanol (E100, hydrous) in any proportion in a single tank of fuel. Ethanol accounts for more than 56 percent of gasoline use in Brazil (including hydrous plus anhydrous ethanol), compared with 8 percent in the United States.

Production and use of sugarcane-based fuel ethanol in Brazil began in 1975 when the Alcohol Program (Proálcool) was launched in response to soaring oil prices and a crisis in the international sugar market. The program resulted in new commercial uses for sugarcane and made Brazil a pioneer in the use of ethanol as a motor vehicle fuel. Brazil's development in this area was facilitated by the country's availability of feedstock, a supportive ethanol policy environment, and efficiency improvements in cane production and ethanol conversion processes. Until 1999, the country's supply of feedstock was stimulated by decades of Government support provided through controls over producer prices for sugarcane: the Government set prices along the sugarcane and sugarcane products chain, established production and marketing quotas for both sugar and ethanol, and was the only domestic distributor and exporter of sugar and ethanol (OECD, 2005). To stimulate demand, the Government implemented ethanol legislation that established mandatory blending targets and subsidized continuous advances in the automobile industry for more efficient use of ethanol.

Brazil is now challenged with sustaining production growth in the ethanol sector to meet increasing domestic demand and, at the same time, maintain its position as a major supplier of ethanol to world markets that are growing rapidly in response to their own ambitious targets for renewable energy use. This study examines the historical development of Brazil's ethanol programs, the factors that gave shape to the current structure of the industry, and the potential challenges over the next decade.

Ethanol Feedstock, Industrial Processing, and Distribution

The sugarcane sector is a major component of the Brazilian economy. With a value added of around $33 billion annually, the output from the sugarcane and sugarcane products chain makes up about 2.3 percent of Brazil's Gross Domestic Product (GDP) and 15 percent of value added in Brazilian agriculture (IBGE, 2010b). In 2008, the sector generated 4.4 million jobs—1 million directly and 3.4 million indirectly (CAGED, 2009).

Sugarcane Production

Sugarcane is cultivated in most Brazilian States. The spatial distribution of sugarcane in Brazil is divided into five regions (Southeast, South, Center-West, North, and Northeast) defined by State boundaries and similar characteristics regarding climate, topography, soil, natural vegetation, and agricultural land use (fig. 1).

Sugarcane in Brazil is grown under rainfed conditions, and planting occurs year round, but 75 percent of planting takes place in January-June (Southeast, South, and Center-West), and May-October (North-Northeast) (CONAB, 2010). New cane cultivars with different maturation times allow for continuous harvesting over 8 months (April-November) across regions in Brazil, which contributes to low costs of production (IDEA, 2006).

Sugarcane area has expanded considerably, growing 3.3 percent per year from 1975 to 2010, four times the annual average growth for total area harvested for all field crops in Brazil. Harvested cane area rose from 4.3 million hectares in 1990 to 9.2 million hectares in 2010, equivalent to 15 percent of total area harvested in the country (IBGE, 2010a). Sugarcane is Brazil's third-leading crop in terms of area harvested, after soybeans (23.3 million hectares per year) and corn (12.9 million hectares per year). About 68,000 farms in Brazil produce sugarcane (IBGE, 2010a).

Growth has not been steady, as the expansion of area harvested to sugarcane has responded to policies affecting both the sugar and ethanol sectors, as well as external market circumstances. During the the first 14 years of Proálcool (1975-89), area harvested to sugarcane grew at a rapid 5.6 percent per year, only to slow in the 1990s, particularly in the Northeast, because of financing difficulties (IBGE, 2010a). Since 2003, after the introduction of the first flex-fuel vehicles in Brazil, sugarcane area has grown 9 percent annually, with close to 4 million new hectares added during the period (IBGE, 2010a).

Brazil's sugar industry was first established in the Northeast region, which includes Alagoas and Pernambuco States;[1] the region now (2010) accounts for 10 percent of the country's sugarcane production. Characterized as a region with relatively low population and low per capita income, the Northeast has benefited from its geographical proximity to the U.S. market and the Brazilian Government's allocation of the U.S. sugar import quota to Brazil.[2]

[1]UNICA reports that "initially, the most productive region and site of the country's first sugar-producing center was the present-day Northeastern State of Pernambuco, run by Portuguese Crown appointee Duarte Coelho; eventually, sugarcane spread to areas in the present-day States of Bahia, Rio de Janeiro, and São Paulo" (UNICA, 2010a).

[2]For fiscal year 2010, Brazil's allocation was 152,691 tons.

Figure 1
Brazilian States and regions

Source: USDA, Economic Research Service using data from IBGE (2006).

The Southeast-South regions, with better soils and climate than the other regions, are ideal for the cultivation of sugarcane and many other crops (e.g., coffee, citrus, feed crops).

São Paulo, in the Southeast region, is Brazil's leading cane-producing State and accounts for two-thirds of total sugarcane production (table 1). From 1990 to 2010, sugarcane area in São Paulo increased just under 5 percent per year, or more than 3 million hectares over the period. About 20 percent of this amount, or 644,000 hectares, was previously planted to coffee, corn, and soybeans. Typically, in any given year in the Southeast-South regions, about

Table 1
Cane area, yields, and production in Brazil, by region and State

Major sugarcane regions/States	Area planted to sugarcane 1990	2000	2010	Average annual growth, 1990-2010	Yields, 2010	Production, 2010
	Hectares (thousands)			*Percent*	*Tons/ha*	*1,000 tons*
Brazil total	4,273	4,805	9,191	3.7%	79.7	729,561
Southeast	2,357	2,979	6,001	4.5%	83.4	500,639
São Paulo	1,812	2,485	5,034	4.8%	85.0	427,946
Minas Gerais	298	291	752	4.6%	81.6	61,343
Northeast	1,477	1,061	1,274	-0.5%	56.4	71,867
Alagoas	559	448	416	-0.5%	61.8	25,708
Pernambuco	467	304	427	-1.1%	54.0	23,053
Center-West	216	373	1,200	8.4%	82.1	98,476
Goias	98	139	573	8.5%	82.9	47,526
Mato Grosso	67	99	405	8.5%	86.2	34,851
Mato Grosso do Sul	51	135	222	8.1%	72.4	16,098
South	207	375	689	5.9%	82.4	56,817
Paraná	159	327	653	6.8%	84.6	51,244
North	16	16	27	3.1%	65.3	1,762

Source: USDA, Economic Research Service using data from IBGE (2010a).

12 percent of the cane is rotated to other crops (corn, soybeans, and peanuts) (IBGE, 2010a). Productivity increases are at the center of sugarcane growth. Continuous improvements in sugarcane productivity since the 1970s have boosted yields by almost 34 tons per hectare to the current (2010) national average of 79.7 tons per hectare (see table 1). Gains in yields, however, differ at the State level and across municipalities; in the most productive municipalities (located in the State of São Paulo) yields are 20-25 percent above the national average (IBGE, 2010a).

Yield variation is linked not only to weather patterns and varieties planted but also to the own crop's harvesting system. Cane harvesting is done by stem cutting, in which the first cut is made 18 months after planting and then annually for 5 years, with yields decreasing for each of the 5 stubble cuts. Yields obtained for the 1-year-old sugarcane decrease 10-30 tons per hectare for the second, third, fourth, and fifth cuts. In any given year, about 20 percent of the cane area on a farm is undergoing replanting, and 13 percent of sugarcane production is from the fifth cut (MAPA, 2009a).

The development of higher yielding cane varieties in Brazil has been a principal focus of research aimed at attaining higher sucrose content and higher stalk water content. Other characteristics of improved varieties include increased resistance to pests and diseases, upright appearance (more suitable for mechanized cutting), lower soil fertility requirements, upright leaves (permitting closer row-plantings), and higher drought resistance. Genetically modified (GM) cane varieties with higher sucrose yields have been available since the mid-1990s (Burnquist and Ulian, 2000), but there is still no approval of GM sugarcane in Brazil.

As a result of gains in yields and area, sugarcane production in Brazil grew 9 percent per year from 2000 to 2010. Brazil is now the world's largest sugarcane producer (730 million tons in 2010), accounting for one-third of world production, ahead of India and China (USDA/FAS, 2010). The participation of independent farmers in the supply of cane to the mills and distilleries remained fairly constant under Proálcool and throughout the early 1990s but has since decreased as Brazilian mills and distilleries now own two-thirds of total area harvested to sugarcane in the country (fig. 2) (IBGE, 2010a).

The average industrial yield measured as total sucrose content (total recoverable sugars, or TRS) is the basis used to determine the price to pay sugarcane suppliers. Before 1997, the Brazilian Government established sugarcane prices prior to the harvest based on regional cost estimates. After deregulation, the São Paulo mills established a new sugarcane payment system named CONSECANA,[3] a private system that incorporates the TRS content in sugarcane (measured as the cane yield in kilograms of TRS per ton of cane) and the prices for sugar and ethanol in both the domestic and the export markets. This system, although not mandatory, is used in other major producing States, such as Paraná, Alagoas, and Pernambuco (Burnquist, 2001).

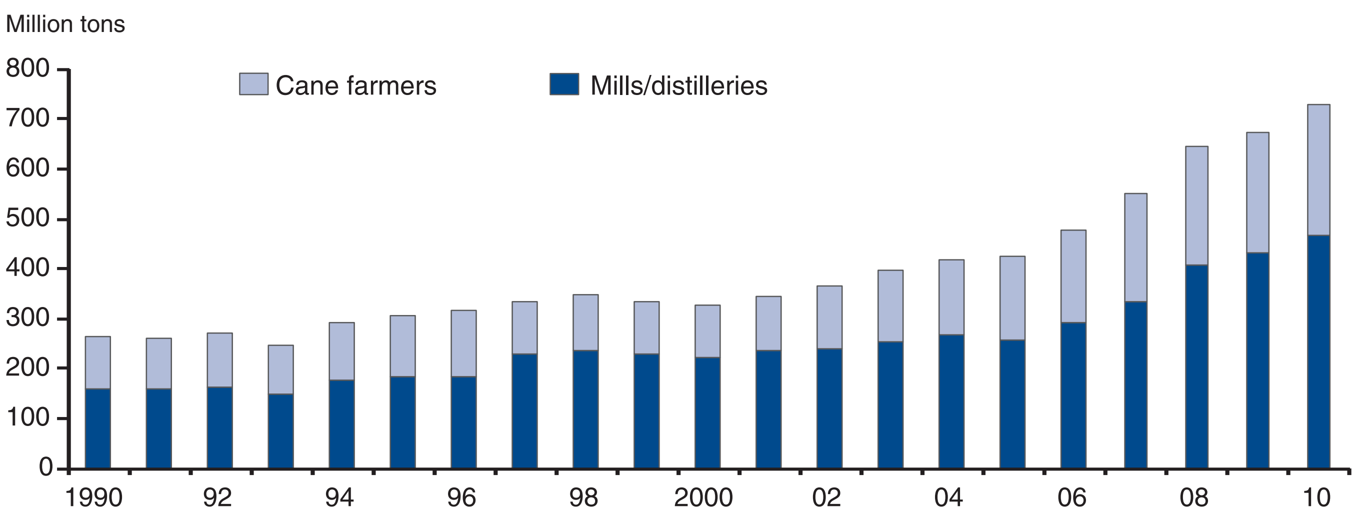
[3]For a detailed description of the system, see Burnquist, 2001.

Large sugarcane farms can reduce production costs through economies of scale; Brazilian mills and distilleries are more responsive to sugar price changes than individual farmers (IBGE, 2010a).

Ethanol Production Process

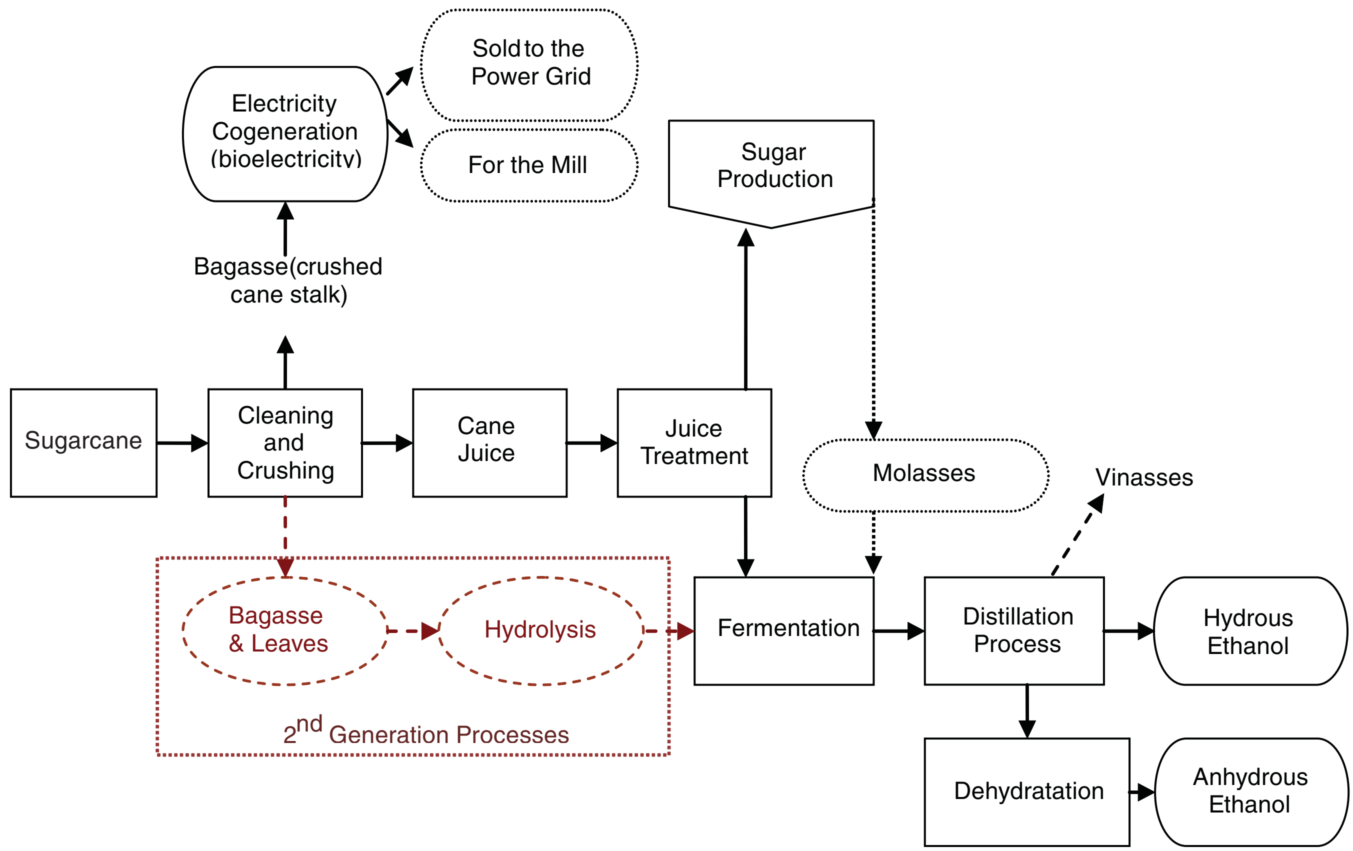
Harvested sugarcane is delivered to mills and distilleries, where the cane stalks are first weighed and samples are taken to measure the sucrose content in the cane juice (at a ratio of 70 to 91 percent) and the fiber content (which ranges from 8 to 14 percent), both of which are inputs to the ethanol production process (fig. 3). After samples are taken, the sugarcane is washed and soaked and the stalks are crushed to extract the cane juice. The resulting cane

Figure 2
Sugarcane production by mills/distilleries and farmers



Source: USDA, Economic Research Service using data from IBGE (2010a) and MAPA (2009a).

Figure 3
Ethanol production process



Source: USDA, Economic Research Service using data from CONAB (2008) and MME/EPE (2010b).

juice output is distilled and purified to obtain two types of ethanol: anhydrous ethanol (a gasoline additive) and hydrous ethanol (a gasoline substitute). On average, 1 ton of sugarcane produces 90 liters of hydrous ethanol and 85 liters of anhydrous ethanol. In terms of sucrose content (or TRS), 1.765 kg TRS yields 1 liter of anhydrous ethanol and 1.6913 kg TRS yields 1 liter of hydrous ethanol (MAPA, 2009a).

A byproduct of sugar production is molasses, used as a raw material to obtain ethanol through fermentation (1 ton of sugarcane will yield 118 kg of sugar and 10 liters of ethanol from molasses) (UNICA, 2008). On average, about 75 percent of ethanol is produced from the cane juice and the other 25 percent comes from molasses (MME/EPE, 2010b).

Vinasse, a potassium-rich byproduct of the distillation process, is recycled as a fertilizer and applied to cane fields. In the past, the disposal of vinasse at river basins posed a major environmental problem for the ethanol industry (de Olivera et al., 2006).

Another sugarcane product is bioelectricity generated for use by the mills and distilleries from the crushed sugarcane stalks (bagasse) and cane trash. Most mills are self-sufficient in energy, and most are able to sell any excess amounts to the electricity grid; the bagasse itself can also be sold (see fig. 3 for processes for converting bagasse through hydrolysis).

For years, the ratio of sugarcane used for sugar and for ethanol production in Brazil was a policy instrument used to regulate sugar production to counter oversupply of sugar and low international sugar prices. The share of sugarcane crushed for sugar or ethanol production depends on the relative prices of sugar and ethanol. In the early years of Proálcool, sugar production accounted for a larger share of cane than ethanol. At times when international sugar prices are high, sugar production and exports take precedence over the production of ethanol. Currently (in 2010/11), around 55 percent of sugarcane crushed is being distilled into ethanol, and the remainder is used for sugar production. The ratio is set by millers before harvest and is based on expected prices and market demand. Mills have a 5- to 10-percent margin for change in the composition of production (CONAB, 2008). Most mills in São Paulo, the largest ethanol-producing State, operate under the 55-45 ratio for ethanol and sugar. In the States of Minas Gerais, Goias, Paraná, and Mato Grosso, more sugarcane is distilled into ethanol than is used for sugar production.

Products derived from industrial processing of sugarcane include sugarcane juice, molasses, bagasse, hydrous ethanol, anhydrous ethanol, and alcohol for industrial uses (plus raw sugar and refined sugar produced at the mixed distilleries/mills). Over 73 percent of total ethanol produced in Brazil is hydrous ethanol, and 27 percent is anhydrous ethanol. Since the introduction of flex-fuel vehicles in 2003, production of hydrous ethanol has increased about 25 percent annually, while production of anhydrous ethanol to blend with gasoline has declined 1 percent annually.

Ethanol yields have more than doubled since the early 1970s, rising from 40 to about 100 liters of ethanol per ton of cane. Millers have increased industrial efficiency by introducing new cane grinding systems, improving distillation processes, and reducing the ethanol processing time. Between 2000 and 2007, ethanol yields from sugar increased by 45 percent (CONAB, 2008). Innovations in industrial processes include the use of byproducts, such as cane molasses to produce ethanol and bagasse to generate heat and electricity. Molasses use for producing ethanol increased 9 percent annually in 2000-2009, and the use of bagasse grew 8 percent per year in the same period, which reflects processors' increasing use of cane byproducts for ethanol production (table 2).

Ethanol Plants and Regional Production

In 2010, Brazil had 430 ethanol-producing plants (distilleries and mixed sugar-ethanol processing mills) (UNICA, 2010a), compared with about 170 ethanol facilities operating in the United States (EIA, 2010b). Eighteen percent of the mills/distilleries are large plants processing over 4 million tons annually (most are in the States of São Paulo, Goias, and Mato Grosso), 69 percent are medium-size plants processing less than 2 million tons per year, and 13 percent are smaller plants processing less than 1 million tons per year (CONAB, 2008). In crop year 2009-10, autonomous distilleries crushed 15 percent of the sugarcane crop; these mills are not able to produce sugar (Velasco, 2010).

Table 2
Sugarcane byproducts for ethanol production in Brazil

Ethanol production process	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Inputs (million tons)										
Sugarcane	326.1	344.3	364.4	396.0	415.2	423.0	477.4	549.7	645.3	729.6
Sugarcane juice	73.0	72.9	77.0	89.1	92.0	97.9	107.1	141.3	181.6	172.8
Molasses	7.2	9.0	10.3	11.2	11.8	12.5	14.4	16.2	15.9	16.3
Bagasse	66.3	78.0	87.2	97.3	101.8	106.5	121.2	134.6	144.4	148.0
Ethanol (billion liters)	10.7	11.5	12.5	14.4	14.7	16.0	17.7	22.6	27.2	26.1
Anhydrous	5.6	6.5	7.0	8.8	7.9	8.2	7.9	8.3	9.6	7.0
Hydrous	5.1	5.0	5.5	5.6	6.8	7.8	9.8	14.3	17.6	19.1

Source: USDA, Economic Research Service using data from IBGE (2010a) and MME/EPE (2010b).

Brazil's ethanol plants are concentrated in the Southeast-South region (fig. 4). Most distilleries are located in São Paulo (53 percent), Minas Gerais (16 percent), and Paraná (14 percent). These States include several large cities with high per capita incomes and large automobile industries. The Proálcool program helped attract domestic and foreign investment to these regions to establish sugar mills with annexes for the distilling of fuel ethanol and independent ethanol plants. The newest ethanol-producing region is the Center-West (Goiás, Mato Grosso do Sul, and Mato Grosso).

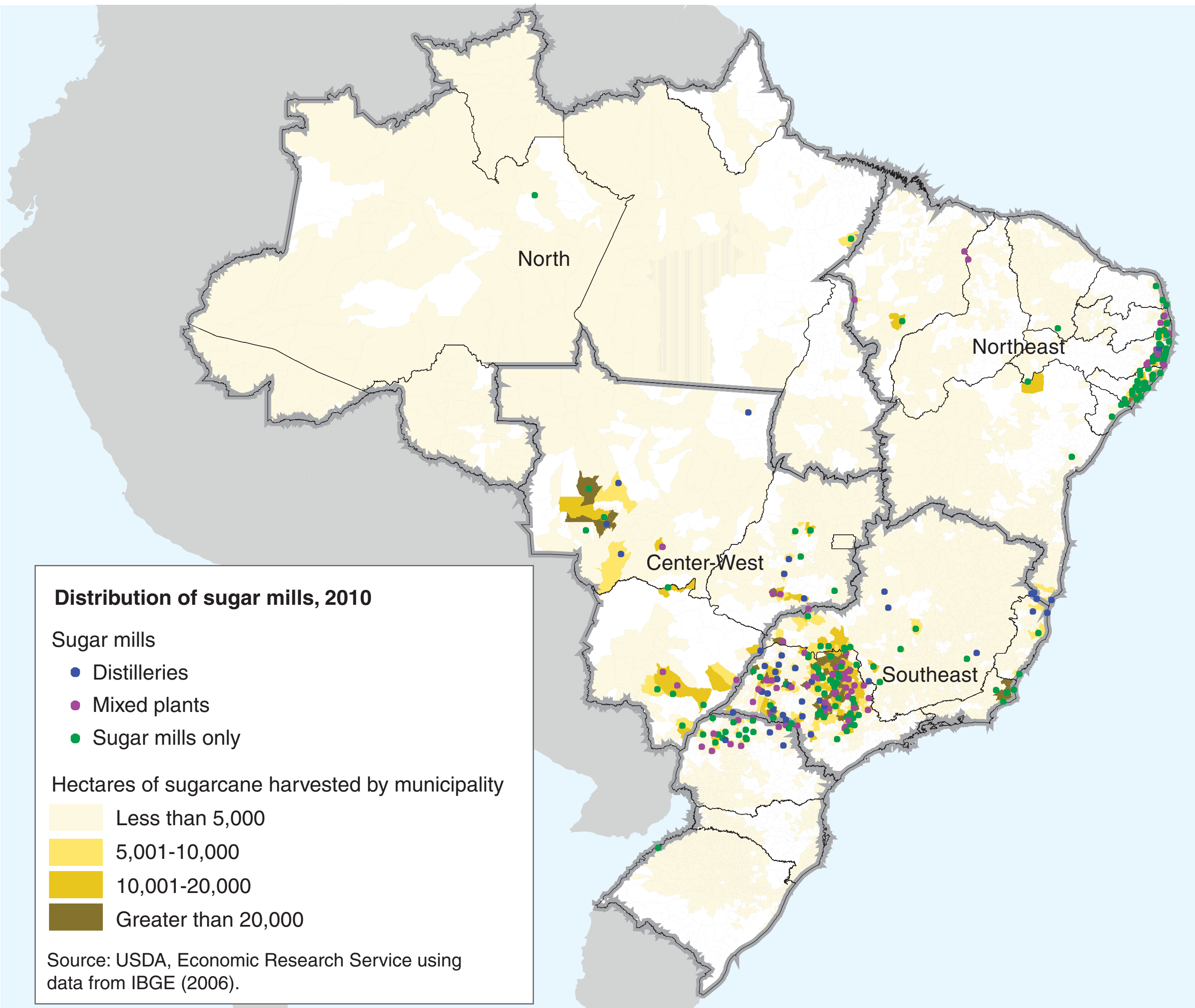
The rapid growth of the industry in Brazil is evidenced by the large number of plants established over the past 5 years alone: since 2006, 138 new ethanol plants have come into production, with most (94) located in São Paulo (ANP, 2010). From 2000 to 2009, ethanol production increased 11 percent per year, reaching 26 billion liters in 2009 (ANP, 2010). In 2009, São Paulo distilled 15 billion liters of ethanol (58 percent of total production in Brazil), including 10.9 billion liters of hydrous ethanol used in flex-fuel cars (57 percent of total) and 4.2 billion liters of anhydrous ethanol for blending in gasoline (59 percent of total). In that same year, Minas Gerais and Paraná distilled 2.3 billion liters and 1.9 billion liters of ethanol, respectively (table 3). Three-fourths of this amount distilled was for flex-fuel cars.

In the Center-West region, output has increased 15 percent yearly since 2000, above the rates of growth for all other regions and Brazil as a whole, a reflection of new investments in cane production and distilleries being set up in Mato Grosso, Mato Grosso do Sul, and Goias.

Ethanol Production Costs

The average cost of producing ethanol at Brazilian distilleries in 2008 was estimated at $0.48 per liter (table 4). Costs include feedstock costs, labor expenses, interest payments on operating loans, energy costs, and fixed costs, such as depreciation. Average production costs for ethanol in Brazil are estimated to be 58 percent lower than those for corn ethanol produced in the United States, 30 percent lower than those for wheat ethanol, and 28 percent lower than those for beet ethanol produced in the EU (F.O. Licht, 2006). Brazil's production costs are lower because of the competitive pricing

Figure 4
Distribution of mills and distilleries, 2010



Source: USDA, Economic Research Service using data from IBGE (2006).

of the raw material (sugarcane), as feedstock purchases represent the largest cost component. In 2009-10, feedstock purchases accounted for 60 percent of total ethanol production costs in Brazil (UNICA, 2010a). Average Brazilian ethanol production costs dropped from a high of $0.47 per liter in 1996 to average levels of $0.21 per liter in 1998-2002 (table 4). Distillers' costs have since increased due to higher energy, fertilizer, and land prices, and they reached a new high of $0.48 per liter in 2008.

Ethanol costs in Brazil vary across regions as well—costs are lowest in the Southeast-South, where the bulk of the country's sugarcane is produced and sugarcane costs are lower. The cost of producing ethanol also varies by the time of year, as supplies of the raw materials fluctuate. Of significant importance to cost competitiveness in the sector are gains in industrial efficiency at the mill. Since 2000, industrial yields for ethanol production have grown 4 percent per year—double the rate in 1990-99, as farmers have continually adopted new and more efficient technologies (fig. 5).

Table 3
Brazil's ethanol plants and ethanol production by State

Plant location regions/States	Plants in 2009	Ethanol production in 2009
	Number	*Billion liters*
Southeast	**314**	**17,676**
São Paulo	259	15,041
Minas Gerais	41	2,284
Rio de Janeiro	8	113
Espiritu Santo	6	238
Northeast	**71**	**2,211**
Alagoas	20	791
Pernambuco	21	469
Other	30	950
Center-West	**63**	**4,263**
Goias	33	2,122
Mato Grosso	10	810
Mato Grosso do Sul	20	1,331
South	**39**	**1,901**
Paraná	37	1,899
Rio Grande do Sul	2	2
North	**5**	**52**
Total number of distilleries/capacity	492	26,103

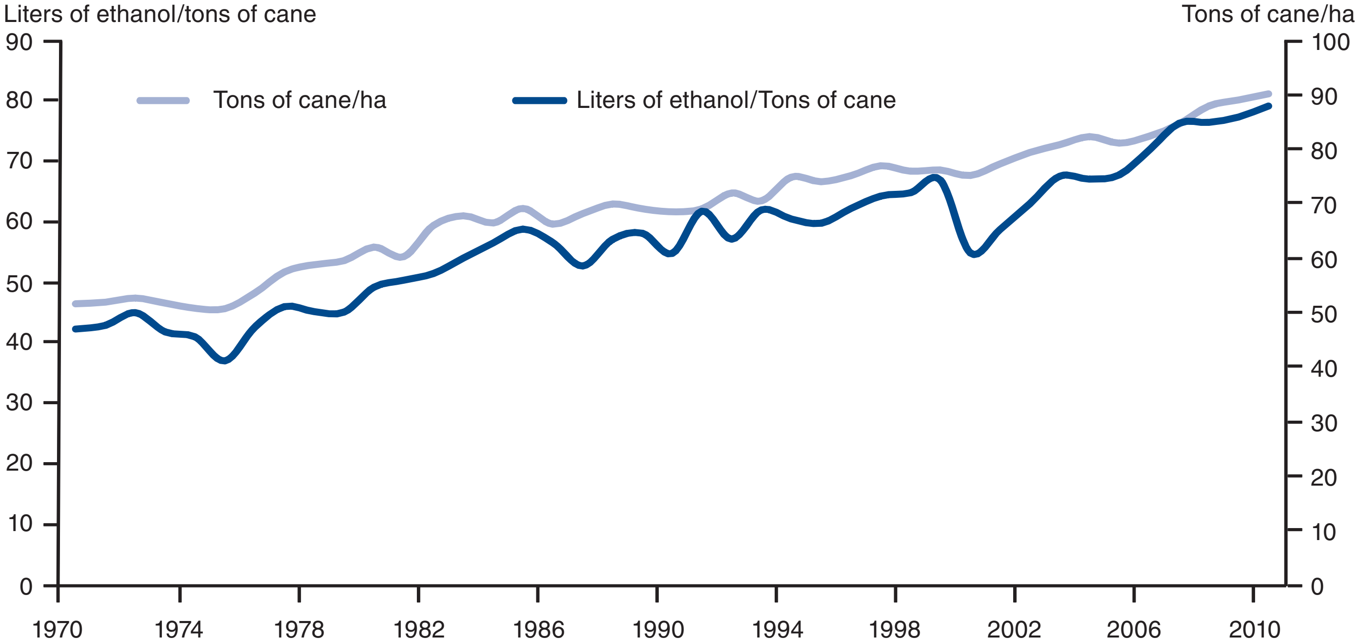
Sources: USDA, Economic Research Service using data from MAPA (2009) and MME/EPE (2010b).

Table 4
Ethanol production costs in Brazil

	1996	1998-2002	2005	2006	2007	2008
	Dollars per liter					
Operating costs	**0.3720**	**0.1603**	**0.1880**	**0.2156**	**0.2336**	**0.3837**
Feedstock (cane)	0.1926	0.0835	0.0907	0.1127	0.1091	0.1496
Labor	0.0737	0.0228	0.0309	0.0356	0.0493	0.0960
Maintenance	0.0109	0.0065	0.0121	0.0146	0.0141	0.0354
Chemicals	0.0281	0.0142	0.0132	0.0138	0.0164	0.0185
Energy	0.0035	0.0021	0.0060	0.0059	0.0070	0.0090
Interest payments on working capital	0.0023	0.0012	0.0024	0.0025	0.0044	0.0078
Rent	0.0026	0.0004	0.0012	0.0029	0.0028	0.0066
Other	0.0583	0.0296	0.0315	0.0277	0.0305	0.0608
Fixed costs	**0.0933**	**0.0451**	**0.0325**	**0.0373**	**0.0662**	**0.0961**
Depreciation	0.0903	0.0428	0.0312	0.0360	0.0633	0.0896
Other	0.0029	0.0023	0.0013	0.0012	0.0029	0.0065
Total	**0.4653**	**0.2054**	**0.2205**	**0.2528**	**0.2998**	**0.4798**

Source: USDA, Economic Research Service using data from IBGE (2010b).

Figure 5
Productivity of Brazilian ethanol and sugarcane



Source: USDA, Economic Research Service using data from MAPA (2009a).

Delivery costs from the mills/distilleries to collection centers range from $0.10 to $0.14 per liter (SIFRECA, 2010), bringing total costs of ethanol delivered to the collection (wholesale) centers to $0.39-$0.43 per liter ($1.48 to $1.63 per gallon) in Brazil, compared with around $0.60 per liter ($2.45 per gallon) in the United States (EIA, 2010b).

Current installed capacity for ethanol-only pipelines in Brazil is 10 billion liters, equivalent to just 2.4 percent of total global use (TRANSPETRO, 2009). An earlier study found that pipelines account for 76 percent of ethanol transported from the mills/distilleries to the collection centers, roads account for 16 percent, and waterways account for 8 percent. Ethanol is transported between collection centers by rail (61 percent), roads (31 percent), and waterways (8 percent). Trucks transport ethanol to distributors' trucks (see Osório Xavier et al., 2008). Delivery costs reflect the regional clustering of ethanol production and the distribution logistics involving an extensive network of highways, railroads, and some waterways. At the lower end of costs are shipments from the Southeast region (São Paulo) to collection centers, with higher costs for deliveries in the Center-West region (ANP, 2010).

Ethanol Prices

Prior to 1997, the Government of Brazil capped ethanol prices at 60 percent of domestic gasoline prices. With deregulation, the Government eliminated the cap but is still intervening in fuel pricing through controls on gasoline prices and a preferential tax treatment on anhydrous ethanol. The Government provides a tax exemption on anhydrous alcohol to blenders as an incentive to ensure ample supply to meet mandated blend rates, but it taxes hydrous alcohol used in flex-fuel vehicles. In addition, ethanol exports are exempt from paying ICMS (value-added tax). Since 2002, average retail prices of ethanol and gasoline (not adjusted for inflation) have risen sharply; ethanol prices have increased faster because gasoline prices are set by the Government and tend to vary less than ethanol prices. Regional variations in prices reflect tax differences across States, supply conditions, and storage and distribution costs (table 5).

For ethanol to be competitive with gasoline, the price of ethanol needs to be two-thirds lower than the price of gasoline (ANP, 2009). This estimate takes into account the lower energy content of ethanol (meaning that ethanol provides fewer miles per liter than gasoline). Since 2000, the nationwide price ratio of ethanol to gasoline has been below this margin, averaging around 60 percent (fig. 6). The price ratio of ethanol to gasoline differs across States because hydrous ethanol is subject to different tax rates. São Paulo, which levies the lowest tax, has the lowest ethanol price in Brazil and serves as the benchmark for domestic and export values (app. table 1).

Ethanol Distribution and Transport Infrastructure

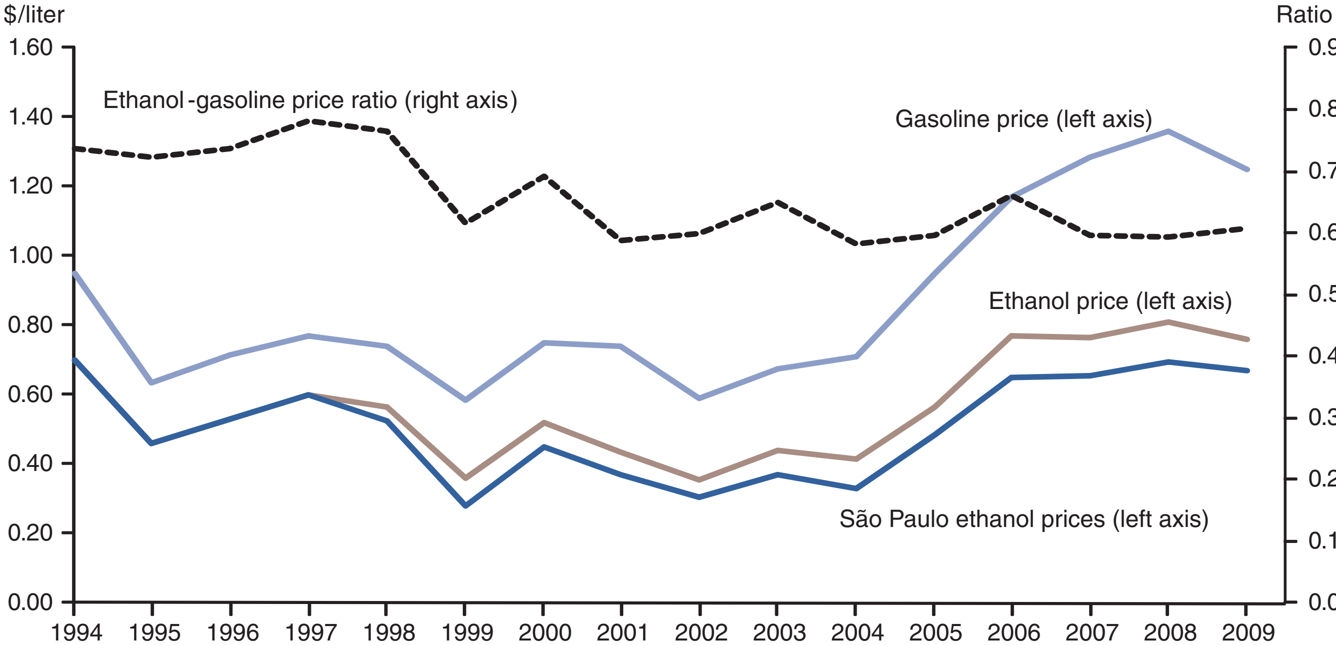
The distribution of ethanol uses the same crude oil transport network controlled by Brazil's State-owned oil company PETROBRAS and its subsidiary company TRANSPETRO, which operates the transport network (6,437 kilometers of pipelines, 156 storage facilities, and 44 export terminals). During Proálcool, PETROBRAS was the sole distributor of ethanol for Brazil's domestic and export markets, but since 1997, mills and distilleries have sold all ethanol for domestic consumption to the 205 Government-

Table 5
Regional ethanol and gasoline prices in Brazil

Regions/fuel type	2001	2002	2003	2004	2005	2006	2007	2008	2009
					Dollars per liter				
Southeast									
Ethanol	0.40	0.33	0.41	0.37	0.50	0.68	0.68	0.72	0.69
Gasoline	0.73	0.58	0.66	0.69	0.93	1.14	1.26	1.33	1.22
Northeast									
Ethanol	0.49	0.39	0.50	0.49	0.69	0.87	0.88	0.96	0.88
Gasoline	0.75	0.60	0.68	0.73	0.99	1.23	1.35	1.43	1.31
Center-West									
Ethanol	0.46	0.38	0.47	0.47	0.64	0.84	0.80	0.89	0.82
Gasoline	0.75	0.60	0.69	0.75	1.00	1.22	1.35	1.41	1.32
South									
Ethanol	0.45	0.37	0.46	0.45	0.62	0.82	0.79	0.83	0.79
Gasoline	0.75	0.61	0.70	0.74	1.01	1.21	1.30	1.38	1.27
North									
Ethanol	0.55	0.45	0.57	0.56	0.76	0.99	0.99	1.05	0.96
Gasoline	0.81	0.63	0.72	0.77	1.05	1.24	1.36	1.47	1.37
National average prices									
Ethanol	0.47	0.38	0.48	0.47	0.64	0.84	0.83	0.89	0.83
Gasoline	0.76	0.60	0.69	0.74	1.00	1.21	1.33	1.41	1.30

Source: USDA, Economic Research Service using data from ANP (2009).

Figure 6
Average ethanol and gasoline prices in Brazil



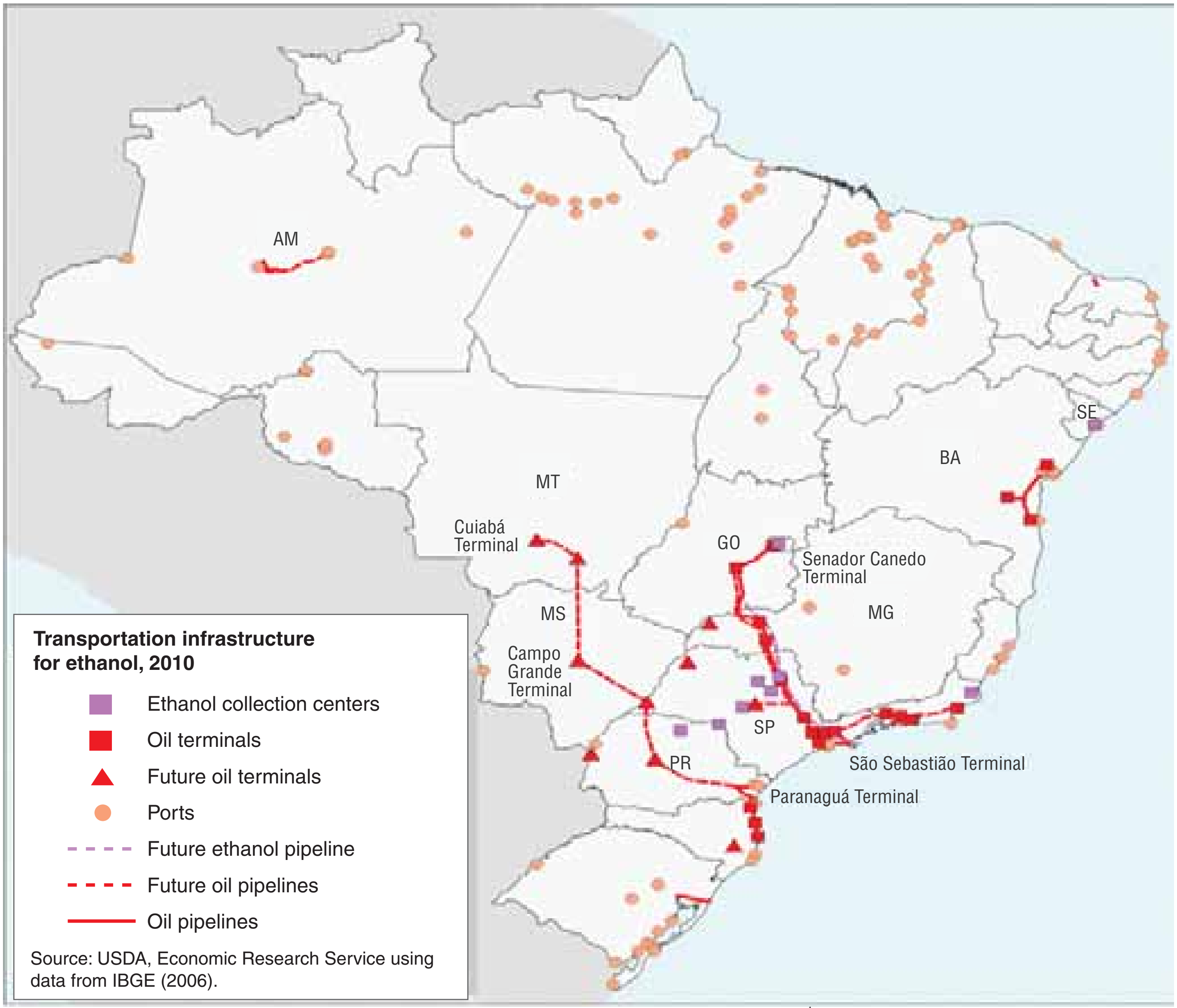
Source: USDA, Economic Research Service using data from ANP (2009).

authorized distributors. Ethanol exports, on the other hand, are handled by mills/distilleries and domestic distributors (CONAB, 2008).

Ten firms control 76 percent of the domestic distribution market, with BR (PETROBRAS retail network of stations) alone holding a 22-percent market share (ANP, 2009). Given the seasonality of ethanol production, distributors purchase ethanol throughout the year based on demand, leaving storage of off-season supplies to mills and distilleries. In 2007, Brazilian mills and distilleries totaled 11.6 billion liters of storage capacity (45 percent anhydrous and 55 percent hydrous ethanol), equivalent to 56 percent of total ethanol production in Brazil that year. São Paulo alone accounted for 56 percent of total mills' storage capacity (CONAB, 2008).

Storage capacity at the plants constructed under Proálcool is about 60 percent of production capacity, compared with 40 percent at new plants (Osório Xavier et al., 2008). After receiving the ethanol from the mills and distilleries, distributors transfer the ethanol to any of PETROBRAS's nine ethanol collection centers: five in São Paulo and one each in Paraná, Brasilia, Rio de Janeiro, and Sergipe. Storage capacity at the collection centers is 105 million liters total, considered low by the Government of Brazil and a constraint to increasing output (ANP, 2009). At the collection centers, the anhydrous ethanol is blended with gasoline ("gasoline A," transferred from the refineries to the collection centers by pipeline) at a ratio that ranges from 20/80 to 25/75 to obtain "gasoline C." Subsequently, both gasoline C and hydrous ethanol (E100) are sold to 469 retail agents who will sell the product in 37,465 gas stations offering pure ethanol for sale side-by-side with gasoline C (E20 or E25) (BR owns 16,372 of these gas stations) (TRANSPETRO, 2010) (fig. 7).

Figure 7
Ethanol transportation infrastructure, 2010



Source: USDA, Economic Research Service using data from IBGE (2006).

Domestic Ethanol Consumption

Brazil is the world's second largest ethanol consumer behind the United States. Brazil's ethanol consumption (22.7 billion liters in 2009) accounts for 31 percent of global ethanol consumption (MME/EPE, 2010b; EIA, 2010a). Over 96 percent of the ethanol consumed in Brazil is for fuel, and the remainder is for industrial use. Domestic ethanol demand increased rapidly during Proálcool, with the introduction of the first pure-ethanol-fueled cars in 1979. During 1979-88, registrations of ethanol-fueled cars increased 43 percent annually, while those of cars running only on gasoline decreased by 13 percent per year. Falling oil prices, rising international sugar prices, and Government efforts to maintain a constant ratio of ethanol to gasoline prices led to ethanol shortages in early 1990 and the eventual disappearance of pure-ethanol-fueled cars from the market by 1999 (ANFAVEA, 2009).

Table 6
Ethanol consumption in Brazil

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Million liters									
Total ethanol consumption	12,386	11,583	12,516	11,912	13,291	13,989	13,435	17,276	22,804	24,269
Anhydrous consumption	5,933	6,139	7,336	7,392	7,591	7,775	5,420	6,512	7,225	6,930
Fuel	5,705	6,008	7,250	7,257	7,451	7,638	5,200	6,227	6,616	6,352
Industrial	228	131	86	135	140	138	220	285	609	578
Hydrous consumption	6,453	5,444	5,180	4,520	5,700	6,214	8,015	10,764	15,579	17,339
Fuel	5,443	4,257	4,344	3,762	4,835	5,656	7,095	10,366	14,666	16,323
Industrial	1,010	1,187	836	758	865	558	920	398	913	1,016

Source: USDA, Economic Research Service using data from MME/EPE (2010b).

The introduction of flex-fuel cars in 2003 revived hydrous ethanol consumption in Brazil (table 6). Owners of these cars may opt to run them on any fuel combination—from 100 percent ethanol to 100 percent gasoline (all gasoline in Brazil is already blended 20 to 25 percent ethanol) based on prices at the retail level. Brazil's vehicle fleet totals 26 million units (about 10 percent of the U.S. fleet size), and flex-fuel cars (about 11 million vehicles) account for 60 percent of total ethanol demand in the country. About 87 percent of new cars and light trucks sold in Brazil are flex-fuel; the remainder (trucks[4] and buses) run on diesel (ANFAVEA, 2009).

Brazil's hydrous ethanol consumption increased an impressive 27 percent annually in 2003-09. Over the same period, anhydrous ethanol consumption decreased 2 percent per year as the lower gasoline demand was not sufficiently offset by increases in the blending rate of ethanol in gasoline. In 2009, hydrous ethanol consumption for fuel reached a high of 16.3 billion liters and anhydrous ethanol consumption reached 6.4 billion liters (table 6). Government policies have played an important role in increasing the demand for hydrous ethanol and for increasing Brazil's flex-fuel vehicle fleet. Automobile manufacturers have been given tax breaks to produce cars that run on hydrous ethanol: in 2004-08, the IPI tax was 6-7 percent lower on flex-fuel vehicles than on gasoline cars, and since December 2008, the new flex-fuel cars (engine displacement of 1,000 cc or less) are exempted from the IPI tax (ANFAVEA, 2009). BNDES-subsidized credit (estimated at $330 million in 2007) available to car manufacturers for operational and R&D activities has also contributed to increases in the flex-fuel vehicle fleet and ethanol consumption (Casotti et al., 2008).

Ethanol demand in Brazil is highest in the Southeast-South (80 percent of total ethanol consumption). The Center-West and the North-Northeast each account for 10 percent (ANP, 2009). Regional consumption mirrors the location of car manufacturing plants and reflects the increasing importance of the newest consumer markets.

Ethanol Exports

The size of global ethanol trade grew from about 550 million liters in the early 1990s to 6.4 billion liters in 2010, after peaking at 16.4 billion liters in 2002 (GTIS, 2010). This growth stemmed from a combination of various

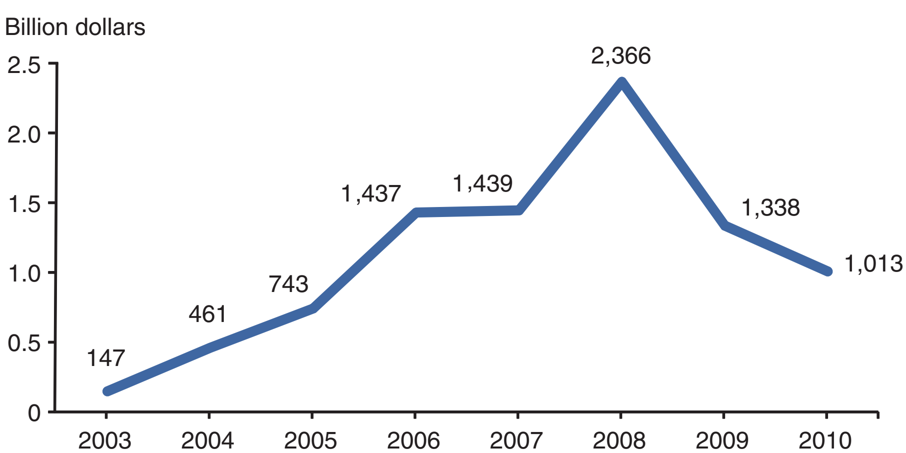
[4]During 1979-89, at the height of Proálcool, a small number of new trucks (10.8 million, or 1 percent of all trucks produced during the period) ran on ethanol.

country regulations for national biofuels targets, incentives, and mandates for the replacement of gasoline consumption with ethanol. Due to increasing demand, mostly from the United States, Europe, and Asian countries, Brazil has expanded its role as a supplier of ethanol.

Up until 2008, Brazil was the world's largest supplier of ethanol, accounting for over 62 percent of the ethanol export market each year (Brazilian shipments reached a high of 5.1 billion liters in 2008) (GTIS, 2010). The value of Brazil's ethanol exports increased 5 percent per year between 2005 and 2010, peaking at $2.4 billion in 2008 as a result of record exports to the United States, which accounted for 32 percent of Brazilian ethanol exports (in value terms) that year (fig. 8). U.S. demand during that period was likely boosted by the effects of the Energy Policy Act of 2005, which mandated the use of ethanol in transportation and the elimination of methyl tertiary butyl ether (MTBE) as an additive in gasoline blending in key markets such as California and New York (Westcott, 2007a). As a result, Brazil's ethanol exports to the United States increased twice as fast as its exports to the world, despite the 45-cent-per-gallon tax credit for "blenders" who add ethanol to gasoline and a 54-cent-per-gallon tariff that increased the price of foreign (mostly Brazilian) imports.

In 2009, a major shift ocurred as conditions changed in major markets and the United States became the world's largest ethanol exporter. During the period, U.S. ethanol prices followed the downward trend in global oil prices, while Brazilian anhydrous ethanol prices remained high and became uncompetitive in world markets (LMC, 2011). Brazil's decline as an ethanol exporter in 2009 and 2010 is attributed to factors other than the global financial crisis that started in September 2008, including a strong domestic market, lower supplies due to increased sugar production, and increased sugar exports to India, in response to higher sugar prices. Also, direct exports to the U.S. market benefitted from duty drawbacks, but these were effectively eliminated in October 2008 (Shapouri, 2010). Growing capacity and production of ethanol in the Unites States and the EU-27 further contributed to Brazil's loss of global ethanol market share. As a result, Brazil's ethanol exports in 2009

Figure 8
Brazil's ethanol exports



Source: USDA, Economic Research Service using data from GTIS (2010).

decreased 35 percent to 3.3 billion liters, whereas in 2010 they decreased 63 percent to 1.9 billion liters (GTIS, 2010).

Brazil exports both anhydrous and hydrous ethanol, with hydrous ethanol representing 90-97 percent of the value of ethanol exports in most years. Brazil exports ethanol to more than 80 countries around the world; major markets in 2010 included the EU-27, South Korea, the United States, and Japan (table 7).

Between 2002 and 2009, Brazilian exports of hydrous ethanol to the Central American and Caribbean countries of Costa Rica, El Salvador, Jamaica, and Trinidad and Tobago accounted for 52 percent of Brazil's total ethanol exports. Brazilian ethanol shipped to these countries was re-exported to the United States as anhydrous ethanol under the duty-free Caribbean Basin Initiative (CBI). This program allows a maximum of 7 percent of the United States' previous year's consumption of ethanol to enter duty free. In 2001-02, over 80 percent of Brazil's ethanol exports (a record 21.6 billion liters) were

Table 7
Brazil's ethanol exports by country of destination

Destination	2004	2005	2006	2008	2009	2010
Value			*Million dollars*			
United States	79	70	748	756	135	186
EU-27	73	155	232	679	384	227
Japan	40	90	94	113	109	131
El Salvador	6	42	80	151	22	0
Jamaica	27	40	56	183	152	66
Nigeria	20	34	19	42	49	40
Costa Rica	23	38	35	47	32	0
South Korea	56	64	34	81	140	188
Trinidad & Tobago	2	11	31	99	48	4
Mexico	18	26	17	14	36	20
India	86	110	5	32	125	28
Total	461	743	1,437	2,366	1,338	1,013
Volume			*Million liters*			
United States	416	231	1,514	1,532	272	313
EU-27	314	519	549	1,469	882	419
Japan	201	303	223	261	280	262
El Salvador	26	159	182	352	71	0
Jamaica	132	132	132	405	438	139
Nigeria	84	114	43	92	116	80
Costa Rica	106	125	91	108	100	0
South Korea	238	216	91	185	314	375
Trinidad & Tobago	8	38	64	222	140	7
Mexico	83	95	49	30	74	35
India	439	390	11	66	368	59
Total	2,146	2,502	3,097	5,074	3,296	1,899

Source: USDA, Economic Research Service using data from GTIS (2010).

exported to Jamaica and subsequently re-exported back to the United States under the CBI (GTIS, 2010). During that period, CBI exports to such areas as Southern California and the Northeastern United States were less expensive than corn-based ethanol shipped to the same areas from production centers in the Midwestern United States (Moller, 2005). For 2010, the duty-free CBI import quota for ethanol producers and dehydrators was fixed by the U.S. International Trade Commission at 2.8 billion liters (F.O. Licht, 2010). The 2005 Central America-Dominican Republic Free Trade Agreement (CAFTA-DR) with the United States kept the CBI conditions on ethanol imports by the United States for the signatory countries of the agreement. In addition, the CAFTA-DR agreement set specific duty-free quotas for Costa Rica and El Salvador within the overall CBI quota. In 2005-09, Brazil's ethanol exports to CBI countries averaged 22 percent of total Brazilian ethanol exports but fell to less than 8 percent in 2010 (GTIS, 2010).

Brazil's ethanol exports to the EU have increased rapidly since 2007 in response to several market mandates with new blending ratios. A greater proportion of Brazil's ethanol exports are going to Asia, where both India and South Korea are facing growing ethanol deficits (F.O. Licht, 2010). Despite the large role of Brazil in global export markets, it exports just 13 percent of its total ethanol production.

Brazil's ethanol export operations are highly diversified: in 2008, 153 registered exporters and 126 large firms accounted for about 98 percent of the country's ethanol exports (DECEX, 2009). Only four ports possess the infrastructure needed for ethanol exports: Santos in São Paulo (70 percent of the country's exports), Paranaguá in Paraná (20 percent), Maceio in Alagoas (7 percent), and Rio de Janeiro (2 percent). The large role of São Paulo reflects its large infrastructure of pipelines, storage, and port facilities. Brazil's ethanol imports, which averaged less than 300,000 liters in 2004-08, have increased sharply to 3.1 million liters in 2009 and 22.2 million liters in 2010. In 2010, the U.S. supplied most of Brazil's ethanol import needs (93 percent) (DECEX, 2009).

Most countries use anhydrous ethanol when setting a fuel ethanol standard, but Brazil sets standards for both anhydrous and hydrous ethanol. While ethanol standards in Brazil and the United States have been in place since the 1930s (for anhydrous) and the 1970s (for hydrous), standards in the EU are still being developed in various member countries. Brazil's National Petroleum Agency (ANP) specifies the minimum ethanol content of fuel ethanol to be 99.3 percent, with additional parameters limited to water, color, acidity, and copper content. The U.S. and EU industry standards include additional specifications, and the limits for several of the parameters are different from those in the Brazilian standard, and from one another (ANP, 2009).

The Contribution of Policies to the Development of Brazil's Ethanol Sector

Brazil has established institutions and a proactive regulatory system for encouraging the development of its ethanol sector, which has helped the country become the world's leading producer of renewable energy. Policies and programs complementary to economic development plans were designed to modernize and diversify the Brazilian agriculture sector, to expand the country's agricultural frontier, and to reduce its economic dependence on exports of primary commodities (coffee, sugar, and cocoa). Later, those policies and programs were refined and new instruments were devised in conjunction with establishing and developing the ethanol sector. Current policies support both production and use of ethanol feedstock as well as the development of the ethanol industry.

Policies in Support of Ethanol Feedstock

The most significant agricultural sector-specific policies have been those aimed at making credit available for production and investment. These policies have been complemented by marketing support programs. Underlying these policies have been strong State support and funding of agricultural research, the opening of Brazil's agricultural frontier, and concurrent infrastructure investments.

Credit Availability and Market Price Support

Financial resources available through Government programs at preferential interest rates for sugarcane production have been increasing in both current and real terms since 2000 as a result of two factors: a Government initiative to provide subsidized credit (8.75 percent subsidized loan rates) to producers planting crops in degraded pastureland (up to 2 million hectares annually) and new credit programs (with participation of the Government and private investors) to increase ethanol production. By 2010, credit available for sugarcane had reached an all-time high of nearly $3.1 billion ($1.7 billion in constant 2000 prices), with 47 percent of that amount allocated to operating capital, 16 percent for marketing purposes, and the remaining 36 percent for investment (table 8). Sugarcane mills and their suppliers may receive operating capital credit to fund input purchases, soil preparation, and new plantings of cane stalks for the second through the fifth crop. In 2010, operating credit of $805 million (in real terms) benefited over a third of harvested sugarcane area.

As part of the economic reforms of the early 1990s, the Government created new marketing loan programs for agriculture. These programs, still operational, allow farmers to receive short-term loans based on the forward sale of the commodities. These programs include the Nota Promissória Rural (NPR) (Rural Promissory Note), the Nota Duplicata Rural (DR) (Rural Duplicate Note), and the Cédula de Produto Rural (CPR) (Rural Product Note) (MAPA, 2009b). The value of these loans for sugarcane in 2010 was $277 million (in constant 2000 prices), all under the NPR and DR programs. BNDES investment credit for sugarcane planting has also been increasing significantly

Table 8
Subsidized credit allocations for sugarcane producers and mills

	2006	2007	2008	2009	2010
	Million dollars, constant 2000 prices				
Operating capital	377	688	656	757	805
Sugarcane production by mills	340	648	618	666	745
Sugarcane production by farmers	29	14	1	0	0
Cane replanting (mills and farmers)	7	20	27	32	22
Sugarcane milling	1	6	9	59	18
Cane irrigated	0	0	0	0	2
Cane agricultural zoning	0	0	0	0	18
Forward sales and marketing loans	385	432	340	309	277
Sugarcane producer sales to mills	3	5	2	4	3
Sugarcane producer sales to GOB (NPR,DR)	379	427	339	305	274
Sugarcane producer sales to GOB (CPR)	3	0	0	0	0
Investment	312	397	561	449	618
Sugarcane production capacity	179	320	274	246	376
Cane planting (mills and farmers)	49	34	41	53	36
Sugarcane energy cogeneration	84	43	245	150	206
Total	1,074	1,517	1,557	1,515	1,700

Source: USDA, Economic Research Service using data from BACEN (2010) and BNDES (2009).

in both current and real terms as has subsidized credit under the electricity cogeneration program, which increased 36 percent annually in 2006-10 (table 8).

Opening of the Agricultural Frontier

Although targeted credit policies have clearly benefited sugarcane production, the policies implemented in the 1970s and early 1980s for land clearing provided the greatest incentive for sugarcane cultivation, propelling Brazil to its current position as the world's largest sugarcane producer. To facilitate the opening of the frontier, the Government provided subsidized credit for land clearing, machinery, and production through several regional programs to develop agriculture in the Cerrados (grassland/savannah lands). These programs, which had the most impact in the 1960s and expanded in the 1980s and early 1990s, are credited with the rapid increase in soybean area in the Center-West Cerrados region (Schnepf et al., 2001).

The expansion of soybean cultivation in the Cerrados indirectly benefited sugarcane production, as the opening of the frontier facilitated the movement of oilseed production from the Southeast and South regions of Brazil and enabled sugarcane to move in (Wilkinson and Sorj, 1992).[5] Harvested area of cane in the Southeast and South regions grew 4.4 percent per year in 1960-2008, increasing from 929,000 hectares in the 1960s to 2.3 million hectares in the 1980s, 4.0 million hectares in the 1990s, and 5.2 million hectares in 2008 (IBGE, 2009a).

[5]Wilkinson and Sorj indicate that during the 1960s, the Agronomic Institute of Campinas developed a variety, IAC-2, for cultivation in the low latitudes typical of tropical and subtropical countries. This was the start of genetic improvements that made possible the expansion of soybeans out of the traditional southern States into the Cerrados region.

The opening of the agricultural frontier operated in conjunction with Brazil's Corporation for Agricultural Research (Empresa Brasileira de Pesquisa Agropecuária, or EMBRAPA), the agricultural research agency linked to the Ministry of Agriculture and Food Supply. EMBRAPA's research has focused on developing high-yielding varieties specifically adapted to the tropics of the frontier lands, developing pest-resistant/cost-reducing varieties, and finding new uses for agricultural products (ethanol from sugarcane, electricity from excess cane bagasse). In addition to the varietal improvements attained by EMBRAPA, other Government efforts included the creation of the Campinas Agronomic Institute (Instituto Agronomico de Campinas, or IAC) and the subsequent development of the IAC varieties. This was followed by the 1970s research program at Copersucar—a cooperative of mills and distilleries transformed in 2004 into the Sugarcane Technology Center (CTC), a private nongovernmental organization that developed the SP (São Paulo) varieties. Planalsucar (now Ridesa) developed the RB (República do Brasil) varieties. The most recent program is the private program CanaVialis created in 2003—one of the largest cane-breeding programs in the world (Macedo, 2005).

Policies in Support of Ethanol

While the Brazilian Government has provided support to crops used as ethanol feedstock, it has also implemented policies specifically designed to support ethanol, including price supports, tax exemptions, guaranteed markets along the supply chain, and mandated blending rates. Macroeconomic and trade reforms have also benefited the ethanol sector.

Macroeconomic and Trade Reforms

Many of the Brazilian Government's policy instruments and regulations associated with ethanol have mostly focused on agriculture. However, the import substitution industrialization (ISI) development approach implemented in Brazil (and in other Latin American countries) in the 1950s through the 1970s emphasized industrial growth, resulting in a large domestic automobile industry that provided an outlet for increasing supplies of ethanol. The 1988 Constitutional Reform that required the Government to stop intervening in private economic activities led to deregulation in the sugar/ethanol sectors. The Government continued to set production and marketing quotas and prices in the sugar supply chain until the mid-1990s and remained the sole buyer and distributor in domestic and export markets (OECD, 2005). Deregulation in the sugar sector began in 1995 when sugar prices and sugar exports were liberalized and the Institute of Sugar and Alcohol was liquidated; between 1997 and 1999, sugarcane and ethanol prices were liberalized and the State ethanol purchasing and distribution monopoly was eliminated (OECD, 2005). By 1999, prices of both hydrous and anhydrous ethanol were deregulated and the State ethanol purchasing and distribution monopoly, which determined the timing and quantities of ethanol produced and sold in the domestic market, was terminated.

In 2000, a new energy law created the National Petroleum Agency (Agencia Nacional do Petroleo, or ANP) to regulate the national oil sector. Currently, ANP sets the standards for gasoline and ethanol products and monitors quality and prices charged at the pump by distributors of gasoline and fuel ethanol. In 2001, the Government introduced the CIDE (Contribuição de Intervenção do Domínio Econômico) program that taxes gasoline C and diesel but exempts hydrous ethanol consumers from paying the tax. Monies collected from this tax are earmarked to fund policies to support the ethanol sector, subsidize transportation of ethanol, fund environmental projects related to the fuel industry, and finance transport infrastructure programs (Dolnikoff and Saes, 2009). Consumption of ethanol continues to be regulated indirectly through obligatory blending of ethanol with gasoline, which has averaged 24 percent over the past decade (MAPA, 2009a). More recently, a tariff of 20 percent on imports of ethanol levied in 2001 was removed in 2010.

The 1970s oil crisis and the resulting rise in oil prices occurred when Brazil was importing over 80 percent of its oil needs. At the same time, the sugar sector in Brazil was stressed by low world sugar prices. Thus, in 1975, the Government moved to establish the alcohol program known as Proálcool. This program was designed to replace imported crude oil with domestically produced ethanol by adding ethanol to gasoline. The Government later implemented a policy to promote the use of hydrous alcohol as a gasoline substitute, with the first cars running exclusively on hydrous alcohol introduced in 1979 during the second oil crisis. Proálcool set the mandated blend to 11 percent in 1976.[6] The blend has fluctuated between 11 and 25 percent since then, with the Government adjusting the mix requirement according to supply and demand conditions. In January 2010, the blend level was set at 20 percent, down from 25 percent, as a result of falling ethanol stocks (app. table 2).

During the Proálcool program and throughout the 1980s, the Government financed the installation of distilleries annexed to existing mills and distilleries around the country but principally in São Paulo. The program also provided incentives for the private sector to manufacture ethanol-using cars and for consumers to buy them, thus increasing demand for ethanol. This higher demand, however, could not be sustained once oil prices started to fall by the mid-1980s. The decline in ethanol demand was exacerbated by the Government's fiscal difficulties and the reduction in subsidies to the sector. Compounding these difficulties, the increase in international sugar prices in the early 1990s resulted in a larger share of Brazil's sugarcane being used for domestic sugar production, leaving less for ethanol production. These factors led to severe ethanol shortages by the late 1980s and early 1990s and decreased demand for ethanol-fueled vehicles (MAPA, 2009a).

Credit for Ethanol Production

Financing for the ethanol sector has risen since the mid-2000s, with the amount of credit granted increasing rapidly and new credit programs being implemented. Funding for ethanol reached $904 million in 2010 (in constant 2000 prices). Over 94 percent of the credit was allocated to investments in distilling machinery and equipment, 3 percent went to operating capital, and 3 percent went to marketing (table 9).

[6]The Government of Brazil first authorized the use of a 2- to 5-percent ethanol blend with gasoline in 1931, increasing the blend to 5, 10, and then 15 percent during the 1960s before reinstating the blending practice in 1975 with Proálcool.

Table 9
Subsidized credit allocation for ethanol producers

	2006	2007	2008	2009	2010
	Million dollars, constant 2000 prices				
Operating capital	18	39	20	36	26
Forward purchases and marketing loans	1	1	1	3	29
Ethanol marketing (NPR, DR)	1	1	1	3	29
Investment	145	567	890	862	849
Distilling machinery and equipment	143	554	884	855	849
Other production capacity	3	12	6	7	0
Total	165	607	911	900	904

Source: USDA, Economic Research Service using data from BACEN (2010).

Under the latest (2009-10) Brazilian farm bill, BNDES administered a new ethanol storage program (initiated in May 2009) to offer subsidized storage loans to millers, distilleries, and ethanol cooperatives at a preferential rate of 11.25 percent per year. The agricultural plan allocated $1.2 billion (R$2.31 billion) to finance the storage of up to 5 billion liters (MAPA, 2009b).

Challenges for the Brazilian Ethanol Industry

Brazil's ethanol industry faces several challenges related to economic, environmental, and social factors that may affect the ethanol supply chain (agricultural and industrial). Economic factors include changes in the world price of commodities that serve as a feedstock for ethanol or have other uses that compete with sugar, molasses, or bagasse, and changes in the world price of oil, exchange rate movements, and infrastructure constraints along the ethanol supply chain. Environmental factors include concerns about expansion of area of feedstock in the Amazon and Cerrados regions and the effect on deforestation. Social factors are related to impacts on employment from changes in harvesting and processing technologies that may require less labor.

Changes in Commodity/Oil Prices and the Exchange Rate

Fluctuations in commodity market prices can have a great effect on Brazil's ethanol sector. For example, upswings or downturns in the international sugar price may result alternatively in a scarcity or surplus of ethanol. In 1988, the increase in world sugar prices led to shortages of ethanol in Brazil. Millers compensated with a mixture of ethanol, methanol, and gasoline, lowering the blend rate to 18 percent anhydrous ethanol content in gasoline. As a result, Brazilian consumers lost confidence in Proálcool, and sales of pure-ethanol vehicles dropped dramatically.

More recently, from March 2009 to September 2010, the global sugar production deficit (resulting from lower supplies from Pakistan and Russia) led to a 51-percent spike in international sugar prices (USDA/ERS, 2010). As a result, Brazilian millers are maximizing their output of sugar to take advantage of its high price relative to ethanol prices; at the same time, Brazilian ethanol prices are not being discounted as aggressively relative to gasoline prices to supply markets (LMC, 2011). Rising ethanol prices make ethanol uncompetitive with gasoline in domestic markets (where the flexible-fuel fleet continues to expand) and also erode the competitiveness of Brazilian ethanol in international markets, reducing its potential for exports. In January 2010, the Government responded to ethanol price increases by cutting the mandatory amount of ethanol mixed into gasoline from 25 to 20 percent.

Changes in world oil prices and domestic gasoline prices will affect the stability of the ethanol/gasoline price relationship under the current ethanol-gasoline blending rate. At times when oil/gasoline prices rise, ethanol demand also increases, setting off a surge in investment and construction of ethanol plants. In contrast, when oil/gasoline prices decrease, as was the case in Brazil in 2009, ethanol demand weakens, slowing industry expansion (BNDES, 2009).

Exchange rates have been a factor in the year-to-year shifts in Brazil's ethanol trade. During the latter half of the 1990s, Brazil fought inflationary expectations by pegging its currency to the U.S. dollar. As a result, the value of the Brazilian real on foreign exchange markets was high relative to earlier years, and, by some measures, the currency was overvalued. In the aftermath of the Asian financial crisis of the late 1990s, Brazil responded to pressure on world financial markets by relinquishing the peg with the dollar in January 1999; its currency then depreciated significantly. As a result, the cost of Brazilian products on world markets, including ethanol, has risen. Partly in response to the strengthening exchange rate, the Brazilian Government has moved to increase support to its ethanol sector.

Infrastructure and Transportation Constraints

Infrastructure and transportation constraints along the ethanol supply chain are major obstacles to Brazil's capacity to supply increasing volumes to domestic and world markets. The costs of transporting feedstock are considerable. Fifty-four percent of Brazil's harvested cane is transported about 20 kilometers (1 km = 0.62 miles) from the fields to the mills, and over 12 percent of cane—mostly from larger farms—is transported 40 kilometers or more (CONAB, 2008). As the bulk of ethanol is transported from the processing plants to the PETROBRAS collection centers and to the ports by truck, optimal road infrastructure is critical to maintain future competitiveness of the industry. The cost for truck transportation of the ethanol to ports is high: about $35 to $40 per 1,000 liters from the traditional sugarcane areas in São Paulo and Paraná and $22 per 1,000 liters in the Northeast, where mills are closer to ports (CONAB, 2008).

Poor roads impose even higher costs on Brazil's farmers located in the agricultural frontier in the Center-West region, where new distilleries are being set up and located farther from the ports but where yields are higher. The average distance from the Center-West region to ports is over 1,000 kilometers, and port costs are higher in Brazil than in other countries due to poor port infrastructure. Large investments in maintenance and expansion of road infrastructure are needed to keep up with the expected growth in demand and to lower delivery times and costs. In the past, when Brazil was constrained by infrastructure when exporting sugar, several companies (Copersucar, Cargill, and Cosan) pooled their resources for construction of new terminals for shipping sugar from the ports of Santos and Paranaguá, resulting in a decrease in sugar costs from $40-$50 per ton to less than $10 per ton (CONAB, 2008).

Environmental Concerns From Feedstock Area Expansion

The potential expansion in Brazilian ethanol (and biofuels in general) production needed to meet increases in demand has led to frequently cited environmental concerns about the intensified competition for land currently planted to nonfeedstock crops or being used for grazing. This expansion, in turn, would force other crops further west into the Cerrados and Amazon. According to some detractors of the plan, such a change in land use would likely lead to habitat loss on the frontier (Searchinger et al., 2008). The area under threat is Brazil's "Legal Amazon," an administrative designation that includes the Amazon forest biome[7] plus some areas of savannah in Mato Grosso and Tocantins (these two States are also part of the Cerrados). The Legal Amazon covers 127 million hectares (equivalent to about 1.3 times the

[7]The term "biome" refers to the ecosystem that sustains native plants and animals.

planted U.S. acreage in 2009), and current estimates indicate that one-third of its area has been deforested (IBGE, 2010a).

Activities contributing to the deforestation of the Legal Amazon include cattle ranching, timber extraction, and crop production (principally soybean production). Most of the deforestation is primarily in the State of Mato Grosso. Area planted to cane in the Legal Amazon increased by more than 100,000 hectares between 1996 and 2006, reaching 283,000 hectares in 2007, or 4 percent of the total for the country. Sugarcane expansion in the Legal Amazon has averaged 7 percent per year since 2000. About three-fourths of the expansion occurred in Mato Grosso, but other States in the Legal Amazon (Rondônia and Acre) have also seen increases in cane area since 2000 (IBGE, 2009a).

Although the recent growth of Brazil's ethanol industry has led to rapid land-use changes favoring sugarcane production, the bulk of land conversion has been in the Southeast and South regions. The Government projects that these areas will remain as the most dynamic regions in terms of land-use change (see next chapter in this report for detailed analysis of future area expansion for feedstock cultivation). To curtail the indirect effects from cane expansion (e.g., the transfer of livestock and crop (soybeans, cotton) production to the Amazons and Cerrados), the Government is enforcing regulations for clearing of the land. Brazil's legal framework for the environmental sustainability of food and bioenergy production is included in the Forest Code (Código Forestal) and its Legal Forest Reserve (Reserva Legal, or RL) directive. This directive mandates that farmers outside the Legal Amazon (but located within the Amazon biome) must conserve 20 percent of native vegetation as uncultivated land, while those in the Cerrados (savannah) areas along the frontier with the Amazon are required to keep a reserve of 35 percent; farmers located in the Legal Amazon must conserve 80 percent of the vegetation (MMA, 2008).

But the most significant measure implemented by Brazil to ensuring the sustainable production of sugarcane-based ethanol is the agricultural zoning database, commonly referred to as the Agricultural Zoning Program (AZP). Initiated in 1996 by Brazil's Ministry of Agriculture and Food Supply (MAPA) and EMBRAPA, the AZP for sugarcane explicitly forbids cane area expansion in the most sensitive biomes (e.g., Amazon, Pantanal) or through deforestation of native vegetation (e.g., Cerrados) (Desplechin, 2010).

Changes in Harvesting and Processing Technologies

A second environmental issue with important social implications stems from Brazil's decades-old practice of clearing land by fire. Recent environmental concerns about cane burning and its harmful CO2 emissions are moving the industry toward increased mechanization, particularly in the State of São Paulo, where 46 percent of cane is burned prior to mechanized harvesting and 54 percent is harvested green (IDEA, 2006). As a result, Brazil's new countrywide environmental directive—and one modeled after São Paulo's—defines areas with slopes less than 12 percent as areas apt for mechanized harvesting, which will prevent burning of the cane at harvesting. The schedule for phasing in the practice of increased mechanization in sugarcane cultivation has been set at a 20-percent mechanization adoption rate by 2010, a 40-percent rate by 2014, and a 100-percent rate by 2017.

Despite having positive effects on ethanol production costs, increased mechanization has negative social effects, particularly on cane laborers. In Brazil, harvesting of the cane is done either manually or with mechanical cutters (manual labor accounts for about 71 percent of the harvesting in the Southeast-South and 97 percent in the North-Northeast, employing close to 300,000 workers). The planned increases in mechanization use at harvesting times will affect the workers employed to cut cane. It has been estimated that each mechanical cutter could replace 81 laborers with present technology, but the planned doubling of mechanical cutters by 2015 is projected to lead to an even larger number of cane laborers being forced out of work (CONAB, 2008). To counter this negative effect, a consortium that includes UNICA, the private sector, and international organizations has put in place a retraining program for about 7,000 current and former cane cutters (Velasco, 2010).

Future Perspectives for Brazil's Ethanol Industry

The future of Brazil's ethanol sector depends on feedstock supply, growth in domestic and international ethanol demand, and new developments that might improve the marketing and distribution of ethanol.

Feedstock Supply for Ethanol Production

Brazil's ethanol production will depend on the expansion in feedstock cultivated area, the competition for land with other crops and pasture, increases in feedstock productivity, and efficiency improvements in ethanol conversion processes. The outcome from these factors will, in turn, influence the establishment of new distilleries and the development of infrastructure for the marketing and distribution of ethanol.

Area Expansion for Feedstock Cultivation

Brazil's agricultural area was 76 million hectares as of 2010, and pasturelands stood at 172 million hectares. The scope for cropland expansion in Brazil is estimated at 119 million hectares, with 69 million hectares in Cerrados and 50 million hectares from pastureland conversion (IBGE, 2010a).

Based on USDA long-term yield projections, an additional 12 million hectares of cropland will be brought into production by 2020. The expected rate of expansion for new cropland area in Brazil is one of the world's highest, at 1.9 percent per year over the next 10 years. This expansion is likely to come from converted pastureland (UNICA, 2010a). Sugarcane area is projected to increase from 8 million hectares in 2008 to over 10 million hectares in 2020 (table 10). More rapid sugarcane area expansion is expected in the traditional cane-producing State of São Paulo and in the Cerrados because of increases in capacity utilization in existing mills (continuing the trend of the past 5 years) and the planned opening of new mills now under construction. Brazil's most dynamic region for cane production has been identified around four principal areas based on soil and weather characteristics and lower priced land: (1) the northwestern area of the State of São Paulo; (2) the southwestern area of the State of Minas Gerais (known as Triângulo Mineiro); (3) the States of Goias, Paraná, and Mato Grosso do Sul; and (4) the new cane frontier in the Northeast and North regions (Bahia, Maranhão, Piaui, and Tocantins), where the largest increases in area planted to cane are projected (MAPA, 2010).

Effect of Increased Supply of Ethanol Feedstock on Crop and Livestock Sectors

According to the Government of Brazil, ethanol feedstock production involves competition for land around three separate regions that are engaged in the production of field, food, and tree crops that compete with livestock production: the Southeast-South, the Northeast, and the Center-West. Sugarcane production in the Southeast-South region competes for agricultural

Table 10
Current area and additional area expected in sugarcane by 2020

Sugarcane regions/States	Area in 2008: Cane area harvested	Cane expansion area in 2008[1]	Area harvested to other crops	Pastureland	Forest area	Area expected in sugarcane by 2020
	Hectares					
Brazil total	8,141,228	1,246,447	33,656,496	127,158,308	67,531,310	10,045,121
Dynamic regions	6,612,850	1,162,115	20,478,032	91,639,409	42,249,693	7,525,920
São Paulo	4,538,198	661,874	740,521	8,594,106	2,321,255	1,214,546
Minas Gerais	608,250	141,190	3,664,030	20,555,061	8,805,707	1,454,920
Paraná	594,585	97,723	5,898,355	5,735,095	3,172,889	736,746
Goias	400,400	143,157	2,775,273	15,524,699	5,239,876	1,135,779
Mato Grosso do Sul	252,544	87,434	1,820,126	18,421,427	4,951,044	1,191,619
Mato Grosso	218,873	30,737	5,579,727	22,809,021	17,758,922	1,792,310
Northeast	805,374	69,654	4,127,580	3,380,552	1,672,395	445,061
Alagoas	434,000	23,165	402,138	873,822	223,476	86,963
Pernambuco	371,374	46,489	3,725,442	2,506,730	1,448,919	358,098
New frontier	169,014	14,678	9,050,884	32,138,347	23,609,222	2,074,140
Bahia	101,384	1,427	3,564,586	12,901,698	9,301,335	824,741
Maranaho	48,685	10,554	3,514,901	6,162,692	4,641,773	494,434
Piaui	12,629	257	1,380,279	2,783,101	4,415,465	208,426
Tocantins	6,316	2,440	591,118	10,290,856	5,250,649	546,539

[1]Cane expansion area includes cane area with first-time cane crops and area harvested to other crops for the past two or more harvest periods and currently harvested to cane.

Source: USDA, Economic Research Service using data from IBGE (2010a).

resources with soybeans, corn, tree crops (principally coffee and oranges), and, to a lesser extent, cattle production. In the Northeast, sugarcane production competes with food crops (pulses, tubers, and vegetable crops), corn, and cattle production. In the Northwest region, 45 million hectares are available for agriculture (CONAB, 2008).

The recent growth of Brazil's ethanol industry has led to rapid land-use changes into sugarcane production. For example, in 2007, over 654,000 hectares of land were converted into sugarcane in Brazil (over two-thirds from converted pastureland), and most of this expansion (94 percent) occurred in the Southeast and South regions. In São Paulo, sugarcane area expansion replaced area planted to soybeans (42,185 hectares), oranges (30,397 hectares), corn (17,292 hectares), coffee (2,284 hectares), other crops/livestock activities (9,750), pastureland (242,146 hectares), and deforested land (7,931 hectares) (CONAB, 2008). The share of Brazil's sugarcane being distilled into fuel ethanol is expected to be maintained at around 60 percent through 2019 (MAPA, 2009a).

Technological Advances for Feedstock and Ethanol Production

Since 2000, sugarcane yields per hectare in Brazil have increased by 33 percent, along with sugar content of cane, ethanol yield from sugar, and fermentation productivity (CONAB, 2008). Research on new varieties is expected to continue as mills and independent farmers endeavor to diversify their production mix to protect against pests and disease. Through the use of existing varieties, conventional cane yields are projected to increase 2 percent per year. Productivity growth is expected to continue at a rapid pace, particularly in the State of São Paulo, where the adoption of new cultivars has been the most dynamic. The development of new cultivars to counter the excess humidity in the Northeast-North is also expected to boost productivity (CONAB, 2008). Cana Vialis (a Monsanto group company) is developing new cane varieties with more fiber to triple the value of biomass, thus obtaining larger production of ethanol from the same quantity of sugarcane. Brazil's Sugarcane Technology Center (CTC) and Germany's BASF are jointly developing a GM cane, with yields up to 25 percent higher than those currently available. The future potential for GM cane is not only higher crop yields but a higher percentage of cellulose, which could be used directly to produce ethanol (MME/EPE, 2010a). Brazil's current yields of 90-100 liters of ethanol per ton of cane are projected to increase by 80 percent based on new technologies: ethanol from cellulose and a new technology to further process the sucrose content for ethanol production (MME/EPE, 2010a).

Production Capacity Expansion and Investment Plans

Brazil's ethanol industry is operating at 75 percent of the country's 30-billion liter (7.9 billion gallons) per year installed production capacity. The production capacity of the United States is about 12-13 billion gallons per year (CONAB, 2008; EIA, 2010b). Planned investments include 105 new distilleries by 2013, at a cost of $33 billion (table 11). Since 2004, PETROBRAS has invested in 5 distilleries and plans to construct 15 more and build 2 ethanol pipelines by 2012: a 1,150-km-long pipeline from Buriti Alegre (Goiás State) to the Port of São Sebastião (State of São Paulo) and a 525-km-long pipeline from Minas Gerais to the port in Rio de Janeiro. The new pipelines will allow for the transport of about 8 billion liters of ethanol at a cost of R$0.04, compared with the current R$0.13 per liter by truck (VEJA, 2007).

Domestic and Global Ethanol Demand

Crude oil prices in Brazil are projected to grow 7.4 percent annually in 2009-18, which is expected to lead to lower reliance on fossil fuels and greater use of ethanol (EIA, 2010a). During the same period, a population increase of 23 million and an increase in sales of cars and light commercial vehicles will also help boost domestic demand for ethanol, which is projected to increase 3 percent per year, rising to about 30 billion liters by 2018 (MAPA, 2009c). In Brazil, ethanol use is projected to account for 12 percent of total transport fuel use by 2018 and about 26 percent by 2050 (MME/EPE, 2010a).

In addition to the increased demand for ethanol for transport, additional demand is projected from the increased use of bagasse as a renewable energy source in Brazil. Most sugar mills in the world use bagasse to produce electricity and/or steam; but for most mills, the objective is to produce just enough energy to meet a particular mill's needs during the processing season. Research findings suggest that the use of energy-efficient technology can result in the export of at least five times the amount of electricity that a typical mill consumes while satisfying all of the mill's steam and electricity

Table 11
Brazilian ethanol plants, production, capacity expansion by State

Plant location regions/States	Plants and ethanol production in 2009		Capacity expansion by 2018		
	Plants in 2009	Ethanol production in 2009	Plants under construction operational by 2013	Total projected plants operational by 2018	Projected ethanol production by 2018
	Number	*Million liters*	*Number*	*Number*	*Million liters*
Southeast	**314**	**17,676**	**55**	**27**	**32,454**
São Paulo	259	15,041	28	6	
Minas Gerais	41	2,284	26	16	
Rio de Janeiro	8	113		4	
Espiritu Santo	6	238	1	1	
Northeast	**71**	**2,211**			**2,318**
Alagoas	20	791.2			
Pernambuco	21	469.2			
Other	30	950.1			
Center-West	**63**	**4,263**	**46**	**33**	**6,957**
Goias	33	2,122	23	4	
Mato Grosso	10	810	1	5	
Mato Grosso do Sul	20	1331	22	24	
South	**39**	**1,901**	**3**	**3**	**4,637**
Paraná	37	1,899	3	1	
Rio Grande do Sul	2	2		2	
North	**5**	**52**	**1**		
Total number of distilleries	492		105	63	522
Total production capacity		26,103			46,366

Source: USDA, Economic Research Service using data from ANP (2009) and MME/EPE (2010a).

needs. Bagasse therefore has the potential to become an abundant and stable source of renewable energy, with the consequent global environmental and economic benefits. Brazil's renewable energy plan (PROINFA) projects that bioelectricity from sugarcane bagasse will supply 20 percent of Brazil's electricity needs by 2018, compared with 16 percent in 2008 (MME/EPE, 2010a).

World ethanol trade—estimated at 10 percent of world consumption in 2009 (GTIS)—is projected to expand over the next decade based on both gasoline consumption forecasts and on renewable energy use mandates in the United States, Brazil, the EU, and other countries. Since 2004, several countries have set energy mandates that encourage the use of agriculture-based ethanol in their transportation sectors. Based on these energy mandates, global ethanol trade is projected to increase 18 percent per year in 2011-18, reaching 16.9 billion liters in 2018. Brazil is projected to supply close to two-thirds of this demand (table 12).

A major market for Brazil's ethanol exports will be the United States. The U.S. Energy Independence and Security Act of 2007 includes provisions for a Renewable Fuel Standard (RFS) to increase the supply of alternative fuel sources by requiring fuel producers to use at least 136 billion liters of

Table 12
Brazil's ethanol export market potential

Net importers	2011	2012	2013	2014	2015	2016	2017	2018
				Million liters				
Canada	645	728	810	895	988	1,074	1,158	1,336
European Union	554	682	793	901	1,014	1,141	1,244	1,435
India	91	255	389	498	598	704	810	934
Japan	944	987	1,025	1,061	1,097	1,136	1,170	1,225
South Korea	416	440	461	481	501	523	542	572
United States	1,325	1,863	2,745	4,176	5,027	6,542	8,416	9,712
Colombia	466	500	600	720	864	1,037	1,100	1,269
Rest of the world	893	900	839	758	653	520	496	453
Total global imports	5,335	6,355	7,662	9,490	10,743	12,677	14,934	16,936

Source: USDA, Economic Research Service using data from FAPRI (2008) and USDA/FAS (2009).

biofuels by 2022. The RFS provision establishes a level of 57 billion liters of conventional ethanol by 2015 and at least 80 billion liters of cellulosic (noncornstarch) ethanol and advanced biofuels (including ethanol from sugarcane and biodiesel) by 2022. Under this provision, Brazil has the potential to export ethanol to the United States. The United States currently imposes a 54-cent import tariff on imported ethanol and provides a 45-cent-per-gallon tax credit for "blenders" who add ethanol to gasoline. Findings in a recent study suggest that elimination of the tariff and the tax credit may reduce U.S. ethanol prices by 12 cents per gallon (3 cents/liter) in 2011 and 34 cents per gallon (9 cents/liter) in 2014, which, in turn, may lower prices for consumers (UNICA, 2010b). In the EU, the Biofuels Directive sets a mandatory minimum share of biofuels in total fuel consumption in the transport sector of 10 percent per member State by 2020. Ethanol consumption in the EU is projected to double to 9 billion liters per year by 2020 (FAPRI, 2008), and Brazil is projected to provide the bulk of the EU's 1.4-billion-liter import need, as well as feedstock for biofuel production.

Life Cycle Analysis (LCA) of Sugarcane Ethanol

Over the past few years, several studies have estimated avoided emissions of greenhouse gases from the use of various feedstocks (including sugarcane) to produce ethanol and replace fossil energy (see von Blottnitz and Curran, 2006, for a detailed review of some of these studies). Macedo and Seabra's (2008) analysis of the full life cycle of sugarcane ethanol concludes that ethanol has a significant effect on the environment and a high net-energy benefit. The researchers tracked all the energy used for growing sugarcane and converting the crop to ethanol. They considered the amounts of fertilizer and pesticide required to produce sugarcane and the levels of greenhouse gases, nitrogen, phosphorus, and pesticide pollutants released into the environment. Results suggest that sugarcane ethanol from Brazil significantly contributes to reductions in greenhouse gas emissions (table 13).

Table 13
Total emissions in ethanol life cycle in Brazil (kg CO2 eq/1,000 liters)

	2006	2020
Sugarcane production	416.8	232.4
Farming	107.0	90.6
Fertilizers	47.3	23.4
Cane transportation	32.4	26.4
Trash burning	83.7	0
Soil emissions	146.3	92.0
Ethanol production	24.9	21.6
Chemicals	21.22	18.5
Industrial facilities	3.7	3.2
Ethanol distribution	51.4	43.3
Credits		
Electricity surplus	-74.2	-190.0
Bagasse surplus	-150.0	0
Total	268.8	107.3

Source: USDA, Economic Research Service using data from Macedo and Seabra (2008).

Conclusions

The production and use of ethanol around the world as an alternative to fossil fuel has increased dramatically since early 2000. The volatility in oil prices, combined with energy policies and Government programs in countries around the world to provide economic incentives for ethanol production, are driving the large expansion in global ethanol production (Westcott, 2007b). Ethanol use increased by nearly 350 percent between 2000 and 2010, and world ethanol consumption reached 74 billion liters in 2010. Global ethanol trade increased fivefold over the period.

Due to increasing demand, mostly from the United States, Europe, and Asian countries, Brazil has expanded its role as a supplier of ethanol. Until 2008, Brazil was the world's largest exporter of ethanol on an annual basis, supplying over 62 percent of the ethanol traded in world markets. Based on *USDA Agricultural Projections to 2020*, Brazilian sugarcane-based ethanol production is projected to rise 45 percent during the coming decade, with a growing share of ethanol production projected to be exported in response to demand from Europe, Asian countries, and the United States (USDA, 2011).

Demand for ethanol in major consuming countries is on the rise. While Brazil may be best positioned to fill the growing world demand for ethanol based on its low-cost resource base for ethanol production and its ability to expand sugarcane area and increase productivity of both sugarcane and ethanol production, Brazil's ethanol export supply depends on its domestic ethanol demand, world sugar and oil prices, its currency exchange rate, and the capacity of its infrastructure to move ethanol to ports. All these factors present challenges to the country's ability to expand production to meet rising domestic and export demand.

The expected level of world sugar prices and the prevailing price of ethanol in Brazil's domestic market determine whether its sugarcane is milled for sugar or for ethanol. When world sugar prices are high relative to domestic and world ethanol prices, ethanol exports fall due to reduced supplies. Until 2008, that relationship favored ethanol over sugar. Brazil's domestic ethanol prices depend on domestic demand, which has been rising due to increasing mandated blending rates and the increasing popularity of flex-fuel cars. Rising domestic demand pushes domestic ethanol prices to levels that are uncompetitive in the world ethanol market, with the result that less of Brazil's ethanol enters export channels. This happened in 2009, when the United States replaced Brazil as the world's largest ethanol exporter. U.S. ethanol prices followed the downward trend in global oil prices, while Brazilian ethanol prices remained high and became uncompetitive in world markets. U.S. ethanol exporters express concerns about corn price increases, which will have an impact on ethanol prices, and the linkage between biofuels and food inflation; in contrast, Brazilian exporters are concerned about rising sugar prices and infrastructure bottlenecks.

The complex Brazilian ethanol supply situation may benefit U.S. producers. A more lucrative domestic market for Brazilian producers leading to higher ethanol sales in Brazil and lower shipments abroad, as occurred in 2010, may create export opportunities for U.S. ethanol producers. U.S. ethanol production is expected to continue to grow based on the recent change permitting use of E15 in cars made after 2007 and the renewal of the 45 cents per gallon ethanol blending credit through the end of 2011.

Over the next 10 years, USDA projects a growing share of Brazil's ethanol production to be exported, but the majority of Brazil's ethanol production will continue to be destined for the domestic market. Brazil's mills and distilleries project higher ethanol and sugar exports and higher domestic sales of sugar and hydrous ethanol (and lower anhydrous sales) during the period. As ethanol demand increases, land expansion and shifting of crop and pasturelands for feedstock production is expected to continue. Technological advances led by EMBRAPA and private institutions for higher yielding cultivars will continue to foster industry growth. Likewise, technological improvements in ethanol processing, such as the use of sugarcane bagasse to produce ethanol, will continue to lower costs. Industry concentration is expected to increase in the coming years, largely through mergers and acquisitions. These factors favor the ability of Brazilian ethanol producers to meet demand and ensure that Brazil will remain a dominant player in the world ethanol market over the decades ahead.

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Appendix

Appendix table 1
ICMS value-added tax on biofuels

	Fuel ethanol	Biodiesel
	Percent	*Percent*
North	Pará: 30 Others: 25	17
Northeast	Alagoas, Sergipe:27 Bahía:19 Others: 25	17
Center-West	Goias: 15 Others: 25	17
Southeast	Espíritu Santo: 27 Rio de Janeiro: 24 Sao Paulo: 12 Others: 25	Minas Gerais, São Paulo: 18 Rio de Janeiro: 19 Others: 17
South	Paraná: 18 Others: 25	Rio Grande do Sul: 12 Others: 17

Source: USDA, Economic Research Service using data from FAZENDA (2008).

Appendix table 2

Blending rates in Brazil for ethanol in gasoline content

Date	Region	Blending rate (percent)
1976	Pernambuco São Paulo Alagoas	10 - 11 (Jul-Sep); 11 -15 (Oct-Dec) 11 - 12 11 - 15
1977	Paraná São Paulo São Paulo (metropolitan region) Rio de Janeiro, Ceará RGN, Paraíba, PE, AL, Mato Grosso	10 - 15 (Jan-Jun); 10 - 12 (Jul-Dec) 11 - 13 (May-Sep); 18 - 20 (Oct-Dec) 18 - 20 10 - 12 18 - 20
1978	Northeast Region Ceará, Pernambuco, Alagoas Center, South, North, and Northeast	20 - 23 23 - 25 20
1981	Brazil Center, South, North, and Northeast	15 12
1982	Brazil Center, South Regions	20 20
1984-88	Brazil	22
1989-92	Brazil Brazil São Paulo (metropolitan region)	18 (Mar-Aug); 13 (Sep-Dec) 22
1990	São Paulo (metropolitan region)	22
1992-97	Brazil	22 - 24
1998	Brazil	24
2000	Brazil	20
2001	Brazil	22
2002	Brazil	20 - 25 (May); 25 (Jun-Dec)
2003	Brazil	20 (Jan-Apr); 25 (May-Dec)
2006	Brazil	20 (Feb-Mar); 23 (Nov-Dec)
2007-09	Brazil	25 (Jun-Nov)
2010	Brazil	20
2011	Brazil	18

Source: USDA, Economic Research Service using data from MAPA (2006).

Appendix table 3

Regulatory framework for the development of Brazil's ethanol sector

Feb. 1931	Decree 19,717 orders a 5-percent blending of ethanol in gasoline
Sep. 1931	Decree 20,356 orders the development of the fuel ethanol engine
Jun. 1933	Decree 22,789 creates the Sugar and Alcohol Institute (IAA)
Nov. 1941	Decree-Law 3,855 regulates sugarcane labor contracting
Sep. 1942	Decree-Law 4,722 declares the ethanol industry a national priority
Dec. 1965	Law 4,870 regulates sugarcane and alcohol production
Aug. 1967	Decree-Law 16 regulates alcohol production and trade
Nov. 1975	Decree 76,593 creates the Proalcool program to reduce petrol dependency
May 1979	First alcohol car (FIAT 147); production goal of 1.5 billion liters ethanol attained
May 1981	Establishes sugarcane-ethanol co-generation procedures, economic impact
May 1986	Stagnation of Proalcool program; oil price stabilizes
Apr. 1990	Law 8,029 eliminates the Sugar and Alcohol Institute (IAA)
Feb. 1991	Law 8,176 creates a national fuels stock system
Feb .1992	Act No. 60 establishes sucrose-content based payments for sugarcane
Oct. 1993	Law 8,723 mandates the fuel ethanol mix in gasoline
Sep. 1995	Act 189 liberalizes sugar prices, except for "cristal standard" prices
Aug. 1996	Decree 59,033 creates GERAN to establish the northeastern cane industry
Aug. 1997	Law 7,478 regulates the national fuel system–creates the National Energy Policy Council (CNPE) and the National Petroleum Agency (ANP)
Aug. 1997	Creation of the Ministry Council for Sugar and Alcohol (CIMA)
Jun. 1998	Decree 2,635 creates the Marketing Committee for Fuel Alcohol (CAEC)
May 1998	Creates CONSECANA, a payment system for the cane based on the TRS content and with ORPLANA and UNICA oversight
Jan. 1999	Creation of BRASIL ALCOOL, 250 producers from the Southeast-South regions are required to remove 1.2 billion liters of alcohol from the market
May 1999	Creation of the Brazilian Alcohol Exchange (BBA)
May 1999	Ends Government intervention in sugar-ethanol markets; ends price controls
Dec. 2001	Law 10,336 establishes the Intervention in the Economic Domain (CIDE) tax for gasoline and diesel, exempting ethanol
Apr. 2002	Law 10,438 creates the National Renewable Energy Program (PROINFA)
May 2003	Introduction of flex-fuel vehicles, taxed at a lower rate than regular cars
May 2005	Kyoto Protocol favors use of ethanol in transportation.
Jul. 2008	Decree 6514 enforces Brazil's Forest Code
Apr. 2009	ANP establishes the new designation of fuel alcohol as "etanol" at pumps

Source: USDA, Economic Research Service using descriptive information from MAPA (2006) and MME/EPE (2010b).