Microeconomics of Competitiveness

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Bio-ethanol Cluster in Brazil

Final Paper

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Country Analysis: Brazil

Geography. Brazil is the 6th largest country – similar to the continental US in land mass and home to approximately 200 million residents. The country has vast arable land (600,000 square kilometers) that is concentrated in the southern and northeastern regions.[1] It is rich in wood, agricultural products, minerals such as iron and ore, soy-based products, beef, poultry, and oil. A subtropical climate, abundant water resources, and cheap labor rounds out Brazil's substantial natural endowment. The country is bounded on the east by the Atlantic Ocean, facilitating trade with its two largest trading partners, the US and Europe. Meanwhile, borders with Columbia, Peru, and Bolivia, plagues Brazil with cocaine trafficking and domestic drug use.

Political System. The country was a colony of Portugal until 1822 and is currently a federative republic with elections every four years. After several decades of military rule, elections in the late 1980s ushered in a series of market-oriented presidents, beginning with President Fernando Collor. In 1992 President Collor left office after impeachment on corruption charges, and the new President appointed Fernando Cardoso as finance minister (Amann, 2005, p.153). Cardoso introduced the Real Plan (Plano Real) in 1994 to deal with the country's hyperinflation; that year he was elected president. Although the country witnessed greater macroeconomic stability during Cardoso's two terms, economic growth languished and inequality and poverty persisted. This paved the way for Luis Inácio da Silva (Lula) to take office in 2002. Since then, Lula has addressed the social goals pledged in his campaign while showing fiscal responsibility and aggressively promoting exports (Musacchio, 2008, p.5-6).

Society & Social indicators. Brazil is the fifth most-populous country in the world, and as of 2008, approximately 86% of the population lives in urban areas. Portuguese is the official and primary language, and nearly 75% of the population is Roman Catholic.[2] White (53.7%), mulatto (mixed white and black-38.5%), and black (6.2%) are the most prevalent ethnic groups.

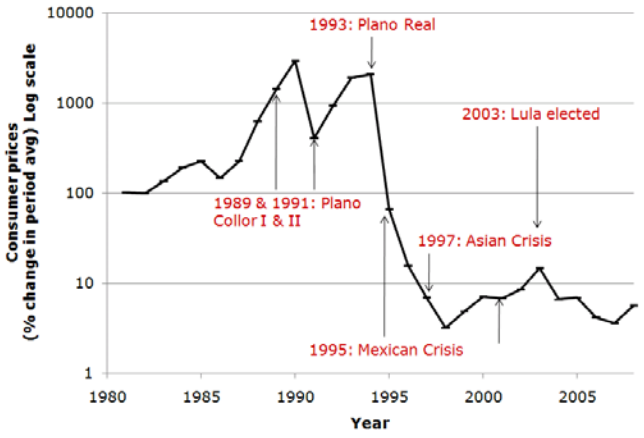
[1] Central Intelligence Agency (2008), *The 2008 World Factbook*, https://www.cia.gov/library/publications/the-world-factbook/geos/br.html, accessed April 2009.
[2] Ibid.

Income inequality in Brazil is an ongoing challenge, although some improvements have been achieved in recent years. The Gini coefficient is ~0.57, which is one of the highest in the world and goes hand-in-hand with unfortunately high poverty rates – a reported 23% (Musacchio, 2008, p. 16). Inequality and indigence can be partly linked to the high concentration of land-ownership that dates back to the colonial era, as 1% of farmers control 46% of the available land (Musacchio, 2008, p.2). These trends were further exacerbated by industrialization, since the new manufacturing sector could not accommodate all the labor displaced from agriculture, as well as hyperinflation in the 1980s. Today, the rich-poor divide is widened by underperforming social services, namely quality and accessibility of health care (GCI 2008: 119, 105 of 134), quality of primary education (GCI 2008: 115 of 134), and reliability of police services (GCI 2008: 108 of 134).

Macroeconomic Environment. Despite the country's great natural endowments, Brazil's economic performance has suffered, in part because of weak macroeconomic policy. Before the 1930s, Brazil's economy was driven by exports of agricultural commodities and mineral resources. The Great Depression and the decrease in the global demand for Brazilian exports forced the country to pursue a different economic strategy, and between 1930 and 1985 Brazil underwent import substitution industrialization. This policy resulted in rapid economic expansion, with 7% annual growth between 1950 and 1980 (Alfaro and Di Tella, 2004, p.2). However, investments in new industries were financed with excessive foreign debt. The oil shocks of 1973 and 1979 pushed the Brazilian current account into severe deficit, which the government chose to finance by increased external borrowing. In 1982, Brazil, like many other Latin American countries, defaulted on its debt.

Throughout the 1980s, Brazil experienced hyperinflation, which was fueled by currency devaluations, government deficits, and indexation of wages and contracts. The economic decline led to the fall of the military regime in 1985. Stabilization programs launched by Fernando Collor, who was elected president in 1989, failed to stop hyperinflation. Nevertheless, Collor had initiated an important shift in Brazil's economic strategy from protectionist state-directed development to trade liberalization and private-sector driven growth (Amann, 2005, p.153). The *Plano Real*, led by Finance Minister Fernando Cardoso, finally curbed hyperinflation; a period of price stability and growth followed (Figure 1).

Figure 1. Brazil experienced hyperinflation until the mid 1990s.[3]



High interest rates, which were necessary to keep inflation under control, resulted in the appreciation of the Brazilian currency and led to a current account deficit. The current account and fiscal deficits were financed by FDI and international borrowing, which made Brazil vulnerable to international financial crises. The Asian and Russian crises of 1997-98 resulted in capital flight from Brazil and devaluation of the real. In order to avoid a recurrence of inflation, the central bank adopted an inflation-targeting framework in 1999 (Alfaro and Di Tella, 2004, p.3). In the following years, Brazil's economic performance was mixed and inequality remained very high. Brazilians' dissatisfaction with the policies of the technocrat government resulted in the victory of the left-wing candidate Luis "Lula" da Silva in 2002.

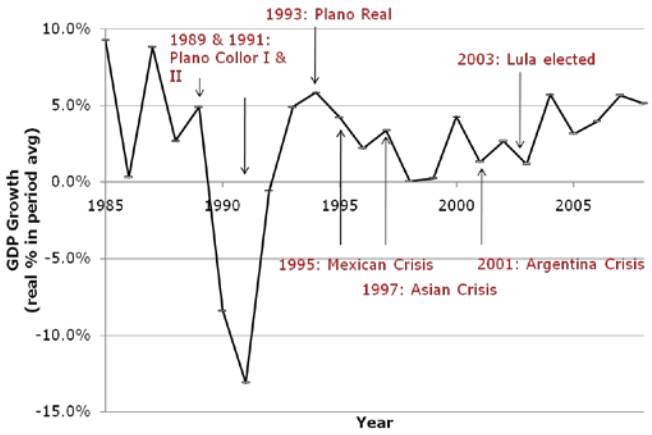
Although Lula was known as a radical socialist for most of his political career, he continued to pursue the market-oriented pro-business policies of his predecessors. However, instead of the macroeconomic firefighting practiced by previous governments, which had resulted in a highly volatile economic growth, Lula has focused on the root causes of Brazil's weak performance: periodic trade deficits and balance of payment crises, caused by fluctuations in world commodity prices; fiscal deficits, which lead to crowding out of private sector investments and high levels of debt; and Brazil's weak microeconomic competitiveness.

Lula's government has pursued highly responsible monetary and fiscal policies, achieving high primary fiscal surpluses. Trade liberalization and export promotion policies, combined with favorable conditions in the global commodity markets, have resulted in current account surpluses. Furthermore, Lula's redistributive

[3] Economist Intelligence Unit, EIU Country Data, via Baker Library, accessed March 2009.

policies have reduced inequality and poverty, creating a considerably more stable macroeconomic environment than in earlier decades (Figure 2).

Figure 2. Brazil's volatile growth trajectory has stabilized under Lula's presidency.[4]

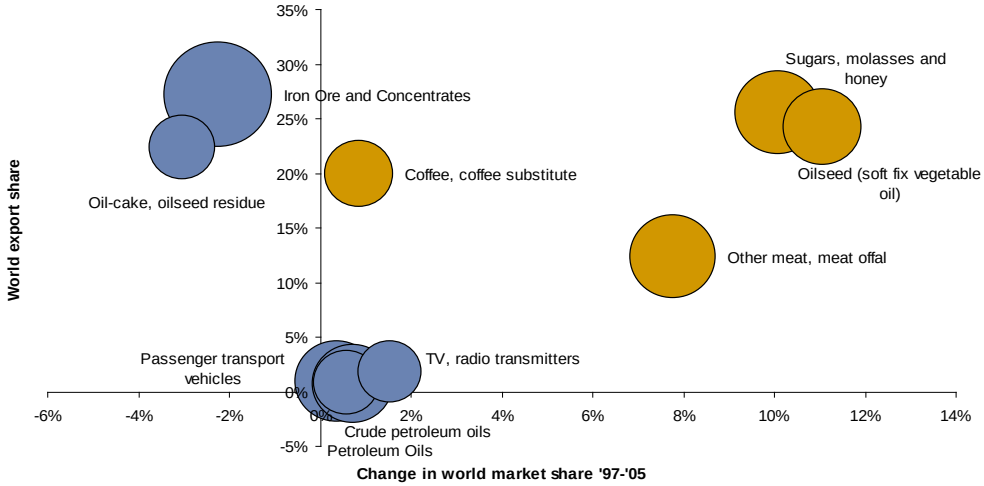


Among the ongoing challenges facing Brazil's economy are high, although gradually declining, interest rates, high interest rate spreads – with lending rates exceeding deposit rates by over 30 percentage points – and high, though improving, official unemployment of 8% (EIU Country Data, 2009). Growth in productivity also has been relatively slow: from 2004 to 2008, labor productivity and total factor productivity both grew at 1.7% CAGR.[5]

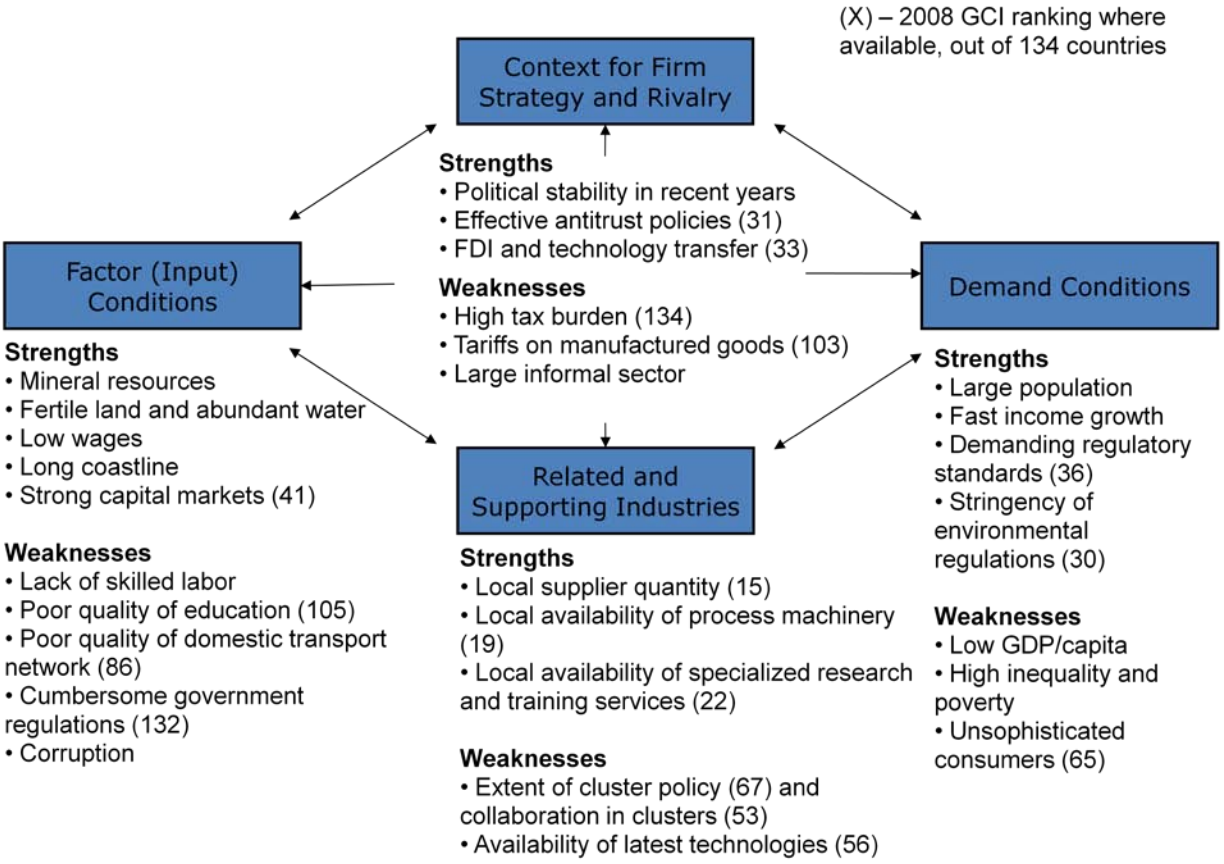
Economic Composition. Rich in natural endowments, Brazil's export industries are heavily agricultural and commodities based. Agricultural products represent the largest and fastest growing sector, accounting for 36% of exports and 7% of GDP (ICC 2005). In terms of volume, the largest export items include iron ore, petroleum oil, coffee, sugar, orange juice, soybeans, meat, and poultry. However, Brazil has also developed a relatively sophisticated industrial sector that constitutes nearly 30% of GDP.[6] This consists of high-value exports such as steel, petrochemicals, and aircraft. These goods, particularly steel, enabled the development of motor vehicles and parts, machinery and equipment. Strong cultivation of these clusters in the future will help Brazil avoid a boom and bust economy that is vulnerable to commodity prices.

[4] Economist Intelligence Unit, EIU Country Data, via Baker Library, accessed March 2009.
[5] Calculations based on Economist Intelligence Unit, EIU Country Data, via Baker Library, accessed March 2009.
[6] Economist Intelligence Unit, EIU Country Data, via Baker Library, accessed March 2009.

Figure 3. Exports are dominated by agricultural products and commodities.[7]



Country Diamond.



Factor Conditions. Brazil's vast natural endowments are undoubtedly its strongest factor conditions. However, many weaknesses in the country diamond derive from the country's institutions, infrastructure, and educational

[7] International Cluster Competitiveness Database, accessed March 2009.

system. Brazil's political institutions rank 71 of 134 countries primarily due to wasteful government spending (GCI 2008: 122), diversion of public funds (GCI 2008: 113), and cumbersome regulations (GCI 2008: 132).

Brazil's transportation infrastructure is also inadequate. The quality of its domestic transport network is relatively low on the global competitiveness index (86 of 134) due to limited paved roads and railway infrastructure outside major cities. Brazil's railway network is concentrated in the densely populated southeast and consists of 28,000 km of rail; this contrasts with Germany, which has 1/28th the land mass and 38,000 km of rail.[8] The quality of Brazil's port infrastructure is also among the worst in the world (GCI 2008: 123). The country has three major ports where the burden of customs procedures is high (GCI 2008: 126), which inhibits trade. Transportation and port logistics that takes five days in other countries averages 39 days in Brazil.

Limited education (GCI 2008: 115) further hinders economic growth. Although public education spending as a percentage of GDP is comparable to that of its neighbors, the quality of primary and secondary education is poor. Adult illiteracy is 12%, though in rural areas this figure is as high as 30% (Rothkopf, 2007, p.487-490). Higher education is even more problematic. Only 20% of the population enrolls in tertiary education, lagging not only the US (82%), but also Peru (35%), Argentina (61%), and Columbia (31%).[9]

The absence of specialized labor partly explains persistently low innovation in the country, as reflected in resident patent filings per million people: 21 for Brazil versus 645 for the US (Rothkopf, 2007, p.452). Weak innovation can further be attributed to low levels of R&D spending, which is less than 1% of GDP for Brazil as compared to 2.5% in the US and Germany.[10] Productivity of R&D spending also appears to be an issue: Brazilian R&D spending is roughly 2x less productive than that of Argentina or the US, as measured by patent filings per million US dollars of R&D expenditure (Rothkopf, 2007, p.452). This productivity gap may be a consequence of the fact that ~ 60% of total R&D in Brazil is publicly funded and weakly aligned with private sector priorities (Ibid, p.449). Additionally, intellectual property protection has been slow to develop; only in

[8] Federal Statistical Office of Germany, "Rail network in Germany 38,000 kilometres long", Press release No.403, September 26, 2006, Federal Statistical Office of Germany Web site, http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/EN/press/pr/2006/09/PE06__403__46.psml, accessed March 2009.
[9] Social Watch, Social Watch Web site, http://www.socialwatch.org/en/portada.htm, accessed April 2009.
[10] UNESCO Institute for Statistics, "Statistics on research and development", UNESCO Institute for Statistics Web site, http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx, accessed March 2009.

1996 did Brazil finally legalize patenting food, chemical, pharmaceutical and biotechnology products (EIU Country Commerce Report, p.35).

Restrictive labor laws also hurt Brazil's overall productivity. Worker protections—including the right to strike, a 44-hour work week and 150% overtime pay—are enshrined in the country's 1988 constitution (Ibid, p.67-71). Moreover, though minimum wage levels are very low in Brazil, even compared with its neighbors, non-wage benefits (namely social security contributions and medical coverage) can increase worker costs by 50-80% (Ibid, p.69). Laws passed in 1998 enabled employers to hire part-time workers (Ibid).

Context for Firm Strategy and Rivalry (CSR). Brazil ranks 125 on the World Bank's Ease of Doing Business Ranking, which is lower than its neighbors Columbia (53), Argentina (113), and Uruguay (109).[11] Between 2001 and 2008 Brazil improved its GCI rankings for CSR, but its performance is still relatively low (GCI 2008: 65). The weak judiciary and legal system, high tariffs, and onerous levels of taxation further compound these costs and underpin the country's substantial informal sector.

"Custo Brasil," the costs of doing business in Brazil, are legendary. It takes an entrepreneur 152 days, five times longer than in Russia, China, or India, to comply with regulatory requirements to start a new business (Musacchio, 2008, p. 12). It is also time-consuming to formally register property, challenging to enforce contracts, and difficult to obtain credit due to limited protections for creditors in bankruptcy (World Bank Group, Doing Business 2009: Country Profile for Brazil, pp. 22, 26, 42). Business crime and violence (GCI 2008: 121) and diversion of public funds (GCI 2008: 113) further diminish the quality of the business environment.

Perhaps the greatest cost of doing business in Brazil is the tax burden (GCI 2008: 134). Recent estimates indicate that on an annual basis, a medium-size company will spend ~2600 hours paying taxes and will give up 69% of total profits (World Bank Group, Doing Business 2009: Country Profile for Brazil, p.33). In an effort to ameliorate the tax regime for high-value investors, recent legislation provides tax exemptions and subsidizing

[11] World Bank Group, Doing Business 2009, via Doing Business Project Web site, http://www.doingbusiness.org/economyrankings/, accessed April 2009.

financing to export-related and technology-oriented industries (EIU Country Commerce Report, pp.26-30). Brazil has negotiated treaties to avoid double-taxation with many countries but notably not the US (Ibid, p.56).

The effect of these myriad of weaknesses may help explain Brazil's low foreign direct investment, at $100B, which has fallen from 4.1% of GDP in 2001 to 1.7% in 2006, compared with 5% of GDP among its neighbors.[12] Nevertheless, multinational companies do consider Brazil an attractive destination for capital, largely because of Brazil's market size and natural endowment; moreover, the country is seen as a port of entry into the greater Latin American market. Brazil allows free movement of capital, and usually does not distinguish between foreign and local investment (EIU Country Commerce Report, p.13). Foreign-owned firms also enjoy the same legal rights as their domestic counterparts, though foreign firms are barred from ownership in select transportation and communications industries (Ibid, p.14).

President Lula has been reluctant to actively move forward with privatization of state-owned enterprises, but he has advanced public-private partnerships to invest in significant infrastructure projects. This initiative was formalized with the 2004 Public-Private Partnership Law; little success can be reported so far, however, due to delays in getting projects approved (Ibid, pp.10-11).

Brazil is a member of the Mercosur bloc (Argentina, Brazil, Paraguay, and Uruguay) that formed in 1991 to eliminate import tariffs and harmonize external tariffs for the vast majority of products traded by these countries (Ibid, p.15).[13] In 1995 the country joined the WTO, where Brazil frequently challenges the US and EU on their agricultural subsidy policies. Meanwhile, Brazil has not fully liberalized its own trade regime (GCI 2008: 103), though import tariffs have fallen to an average of 12.9% as of 2001 and no taxes are levied on exports (EIU Country Commerce Report, p.76).

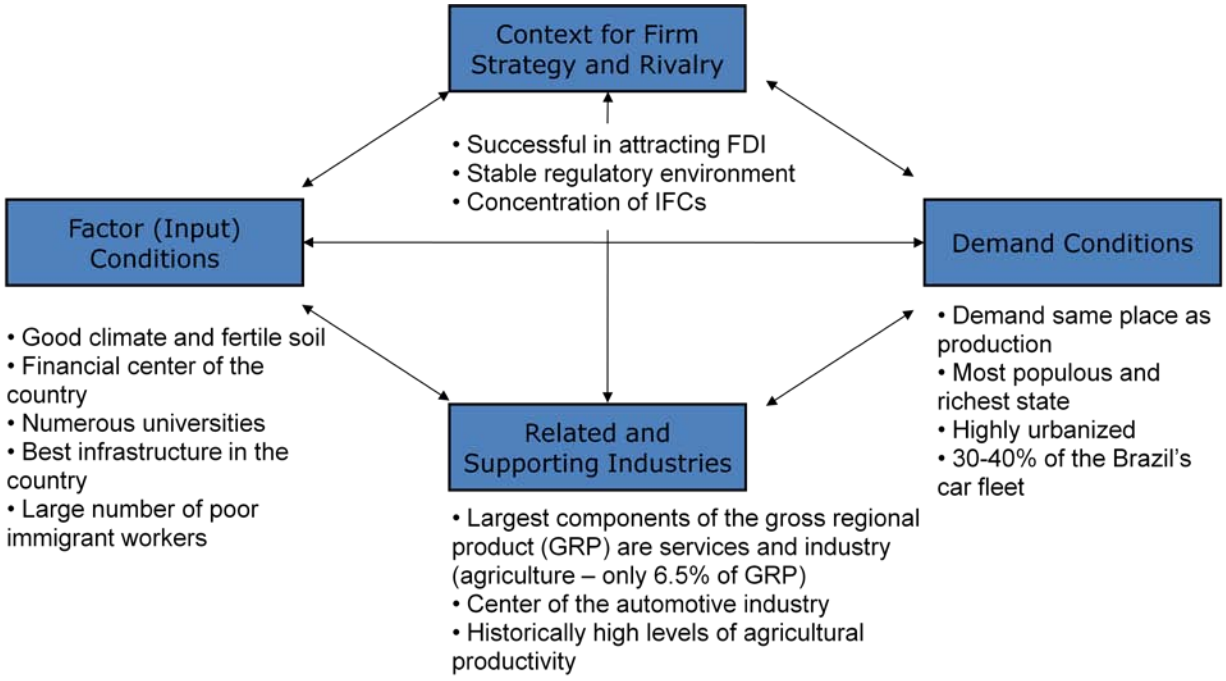
Related and Supporting Industries. Brazil has strong related industries and weak cluster development, ranking 15 for local supplier quantity, 22 for local research and training services and 67 on the extent of cluster policy. These ratings indicate an opportunity for Brazil to enhance its cluster collaboration and policy to take advantage of its strong RSI.

[12] Neighbors here include Peru, Columbia, and Argentina. Economist Intelligence Unit, EIU Country Data, via Baker Library, accessed March 2009.
[13] Mercosur countries expanded the free-trade community in 2003 through an agreement with the Andean Community (EIU Country Commerce Report, p.75).

Demand Conditions. As the fifth most populated country in the world, with developed industries and capital markets, it would seem that Brazil's demand conditions would be extremely powerful. However, as a middle income country with high income inequality and weak buyer sophistication (GCI 2008: 65), Brazil continues to rely on President Lula's export-led growth strategy while it attempts to increase overall domestic demand.

Region Analysis: The State of São Paulo

State of São Paulo Diamond



The State of São Paulo is located in the southeast region of the country. With 40 million inhabitants and a total land area of 248,000 square kilometers, it occupies roughly 3% of Brazil.[14] São Paulo city is the most populated city in Latin America. As the country's major financial and commercial hub, it is Brazil's richest city with an average per capita income of US$9,134 versus the country's average of US$8,300.[15]

Bordering the Atlantic Ocean, São Paulo has a coastline of 600 km. The Tropic of Capricorn passes through the state and roughly marks the boundary between the tropical and temperate areas of South America. Because of its elevation, São Paulo enjoys a temperate climate with abundant rainfall, which makes for some of the most

[14] Brazil Institute of Geography and Statistics, Brazil Institute of Geography and Statistics Web site, http://www.ibge.gov.br/english/, accessed March 2009.
[15] Ibid.

productive agricultural conditions in the country. The majority of Brazil's key agricultural products (coffee, oranges, and sugar cane) are all produced in this region.

The state of São Paulo offers additional strengths that have enabled it to become a major commercial thoroughfare and that lower the costs of doing business in Brazil. São Paulo is the center for capital markets; in recent years, the Bovespa stock market and the BM&F Brazilian options and futures market have grown substantially, benefiting from shareholder protection legislation passed in the late 1990s (EIU Country Commerce Report, pp.20, 61-62). The state is also a hub for universities, as well as scores of IFCs for its primary industries, and boasts a highly literate (94%) and relatively more sophisticated workforce, much of which speaks English (Rothkopf, 2007, p.468-69).[16]

The transportation infrastructure is very well developed within São Paulo with paved roads that connect it to all of its neighbors, railway lines connecting to the port of Santo, waterway via the Tiete River to ship cargo, and three major airports (Viracopos airport is designated for international cargo flights). São Paulo also accounts for 45% of the country's automotive production (Bobovnikova and Miura, 2008, p.31). With 30-40% of the country's car fleet and some of the country's most stringent environmental regulations, the state has been a robust test-site for bio-ethanol use (EIU Country Commerce Report, p.21). São Paulo is also located in the Central-South region, which accounts for 85% of total sugarcane and ethanol production (Kaltner et al, 2005, p.18).

Cluster analysis

Historical Development & Government Policies. In 1526 Portuguese settlers in Brazil started the first sugarcane processing mill. By the mid-1600s the Dutch had transported sugar cultivation skills to the Caribbean, greatly increasing global sugar production capacity. Since then, the sugarcane industry has been subject to recurrent boom-bust cycles as high prices were met with investment in new capacity, leading to subsequent supply gluts.

[16] "Brazil… Poised for Strong Economic and Infrastructure Growth", AT&T, AT&T Web site, http://www.corp.att.com/globalnetworking/docs/networking_in_brazil_att.pdf, accessed April 2009.

In the early 1970s Brazil found itself in just such a position: sugarcane capacity had reached a new high and prices had collapsed. Many Brazilian family fortunes lay with the sugar business, leading some of these families to lobby the government for assistance. Concurrently, the country was reeling from the first oil crisis of 1973. The Brazilian government responded to both of these events with the National Alcohol Program, Proálcool, in order to reduce dependence on foreign oil while simultaneously utilizing the highly productive, but struggling sugarcane industry (Rothkopf, 2007, p. 441).

Proálcool was a program of supply-side and demand-side measures to support the development of the sugarcane ethanol industry. On the supply side, interest rates were reduced for loans used to construct ethanol distillation capacity, while ethanol price floors and guaranteed purchases by Petrobras ensured a minimum revenue stream to producers (Martines-Filho et al, 2006, p.93).[17] In addition, the government itself invested heavily in mills that could switch between ethanol and sugar production (Rothkopf, 2007, p.441). On the demand-side, the government mandated that all gasoline be blended with ethanol. Following the second oil crisis of 1979, the government further required that at least one ethanol pump be available at each fueling station. Demand-side reinforcement continued in the 1980s via tax incentives on ethanol-powered cars, a heavy tax on gasoline, and a ban on diesel passenger cars (Martines-Filho et al, 2006, pp.93-95). A central tenant of the Proálcool program was the agro-industrial and technological development of sugarcane. These R&D intensive activities gave rise to a web of knowledge-oriented organizations and public and private-sector IFCs that have proliferated in subsequent years.

Yet economic crisis, the sharp drop in oil prices, and a temporary shortage of ethanol in 1980s reduced demand for ethanol-powered automobiles.[18] However, the presence of ethanol fuel at virtually every retail gasoline station preserved the future option for ethanol use. The government also maintained its support for the industry, fixing the minimum blend of anhydrous ethanol in gasoline at 22% (Xavier, 2007, p. 6).

As the winds of economic liberalization blew through Brazil in the 1980s and 1990s, many protections were phased out of the ethanol industry. In 1987 Petrobras was no longer required to purchase excess supply of

[17] At the time, Petrobras was the state-owned oil company and monopoly distributor of ethanol. Petrobras is now partly privatized, following the 1997 law that opened up the Brazilian oil sector to foreign investments.
[18] Personal interview with ethanol expert, Caio Carvalhal, April 3, 2009.

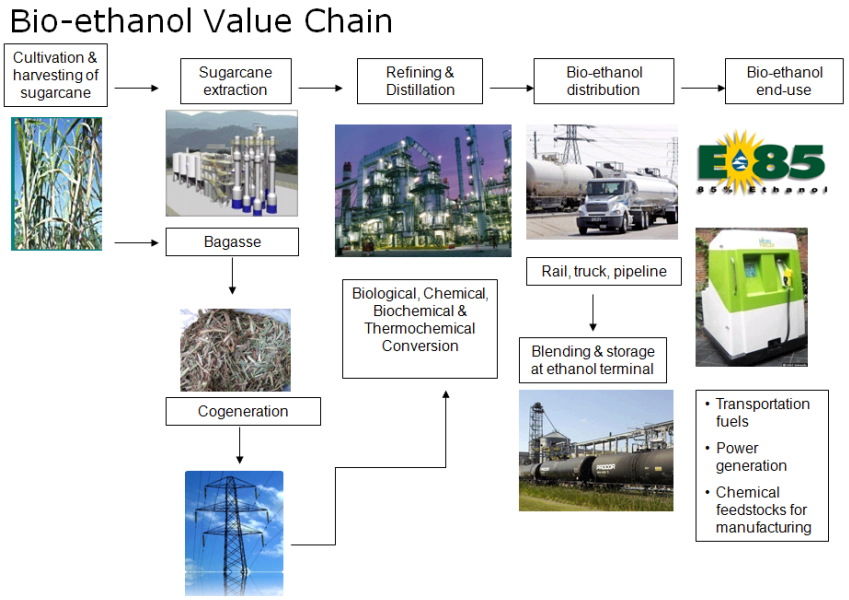
ethanol; ten years later, the price floor on ethanol was removed, and producers were paid based on end-use prices. The Councils of Government Representatives (CIMA/ANP) was also established at this time to monitor deregulation of sugarcane and ethanol markets (Martines-Filho et al, 2006, pp.94-95).

Amidst ethanol price and market liberalization, however, demand for ethanol collapsed as oil prices fell to new lows in the late 1990s. Ethanol was once again brought into favor in the early 2000s, however, amidst skyrocketing oil prices and the development of the flex-fuel engine. And once again, in 2007 the government increased the required concentration of ethanol in gasoline, now to 25% (E25). By creating a market for ethanol and providing a framework of industry support, the government has directly developed a growth center in the Brazilian economy. Today, sugar and ethanol production account for 3.5% of GDP and employ more than 3 million workers.

Natural endowment, a sense of urgency, and committed government policy made Brazil the destination for the world's most competitive ethanol cluster. To be sure, other sugarcane producers were confronted by the oil shocks of the 1970s. Neighboring Argentina provides a case in point. In 1979 domestic automotive manufacturers created that country's first ethanol program. By all indications, however, this initiative lacked clear government participation or support; only recently has Argentina passed legislation establishing tax breaks, fuel blending mandates, and retail distribution infrastructure—pillars of Brazil's bio-ethanol strategy since the 1970s (Rothkopf, 2007, p.63-69).

Furthermore, it seems that today's largest ethanol producer, the United States, also could not have been as competitive as Brazil's ethanol cluster. The US lacks the climate necessary for sugarcane growth (producing only 4 million tons versus Brazil's 528 million in 2008). Thus having to settle for corn, the much more plentiful American feedstock, the ethanol industry in the US has not been able to enjoy the competitive advantages of sugarcane ethanol (Cox, 2007). Corn is four-times less energy efficient and nearly three times costlier to produce; it is also much more land-intensive and more directly compromises the food supply, diminishing its sustainability (Wright, 2008, p. 7; Budny and Sotero, 2007, p. 5).

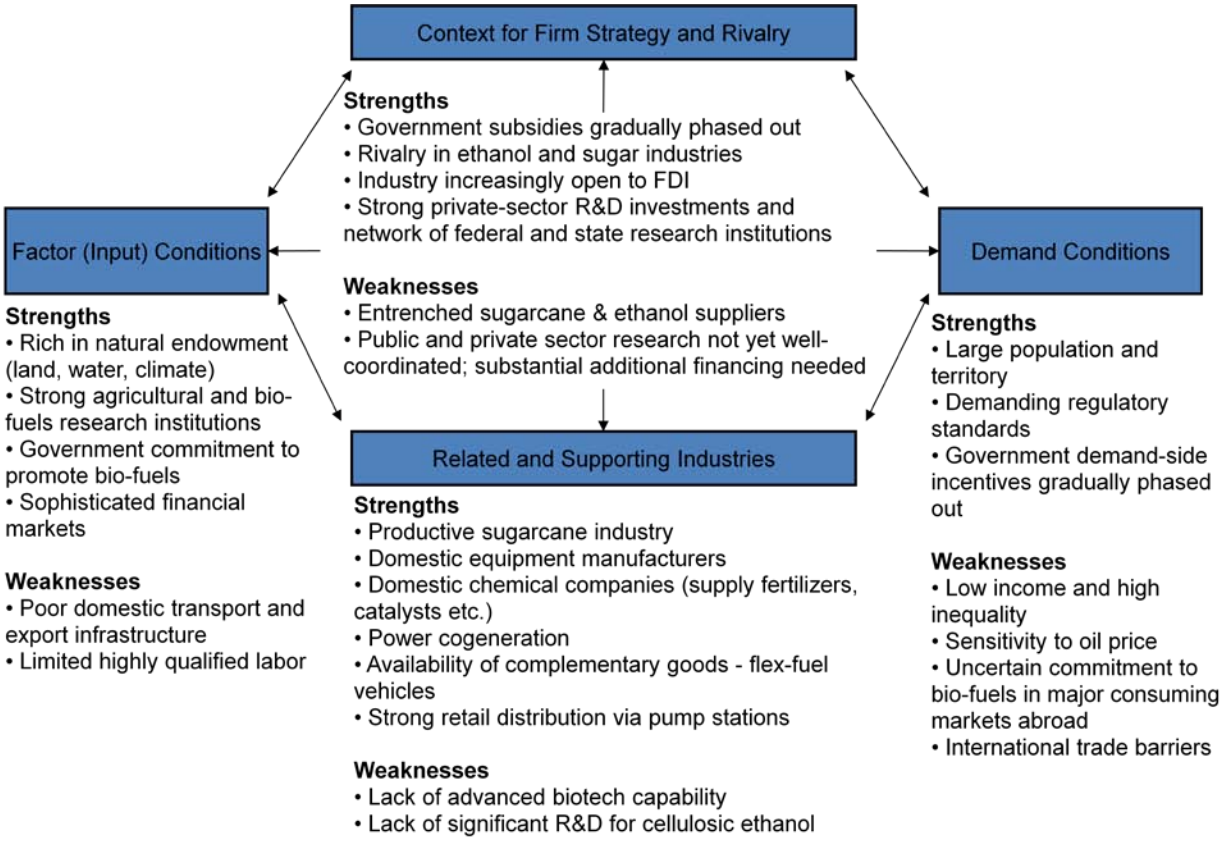
Bioethanol Value Chain.[19] Brazil's bio-ethanol value chain begins with the sugarcane producers cultivating and harvesting sugarcane. Bagasse, sugarcane waste matter with high cellulosic content, can be burned to produce energy for the sugar production process; excess energy can also be sold back to the grid. Production of both energy and sugar is referred to as co-generation. Sugarcane refineries may produce sugar only or both ethanol and sugar. The refineries are frequently located close to the sugarcane plantations and thus transportation and distribution are necessary to move the fuel to domestic retail stations or to ports for export.



Two of the largest bio-ethanol producers in Brazil are Cosan and Copersucar, both of which are integrated sugar and ethanol producers. Cosan sources approximately 40% of its sugarcane needs from third parties and has several collaborations with domestic and foreign partners (Rozenbaum, 2008, p.4). Copersucar is a private cooperative of 90 associates. Its research center, Copersucar Sugar Technology Center, is arguably one of the two most productive research centers in the bio-fuels space.[20]

[19] US Department of Energy, "Alternative Fuels & Advanced Vehicles Data Center", US Department of Energy Web site, http://www.afdc.energy.gov/afdc/ethanol/basics.html, accessed March 2009.
[20] Copersucar S.A. Company Web site, http://www.copersucar.com.br/hotsite/novaempresa/apresentacao_en.htm, accessed March 2009.

Cluster Diamond.



Factor conditions. The ethanol cluster benefits from Brazil's natural endowments (land, water, and climate). Sophisticated financial markets as well as strong agricultural and bio-fuels research institutions are also helpful. However, several weak factor conditions impact the cluster, namely poor domestic transport and export infrastructure as well as limited qualified labor.

Transport by roads, waterways and railways, and export via ports accounts for roughly 10-20% of the ethanol cost structure; thus, quality of transport infrastructure can materially affect the competitiveness of ethanol (estimates based on Babcock, 2006, p. 11). Moreover, poor transportation, as identified earlier, also limits the penetration of ethanol within Brazil and, in the future, to foreign markets.

Another weak factor condition is the limited availability of specialized labor. Currently, 0.8% of the population is graduating as engineers in Brazil, versus 2.2% in the US and 3.3% in Germany (Rothkopf, 2007, p.500). Due to limited enrollment in specialized fields (agrarian sciences, microbiology, and engineering), the country lacks the pipeline of researchers necessary to generate innovations in the cluster. Part of the problem is

that few make it to the point of tertiary education, with only 30% of adults completing secondary school (Ibid, p.499). There is also a capacity problem: only 10% of the students eligible for university education are able to matriculate (Ibid, p.496). Moreover, even among those proceeding to universities and technical education centers, students tend to opt for business and the humanities since high laboratory expenses are usually passed down to students participating in those programs. Finally, the educational system is publicly funded and its curricula are weakly aligned with private sector initiatives. Since the educational gap in Brazil is most acute between urban and rural residents, in the future family-farm agricultural producers might have difficulty integrating into an increasingly sophisticated bio-fuel industry.

Another key challenge remains weak funding for cluster-related R&D. While the public sector in Brazil, as stated earlier, accounts for roughly 60% of R&D spending overall, government funds between 20 and 30% of R&D spending in the bio-fuels cluster. However, greater participation by the private sector appears to have translated into more results-oriented investment and perhaps more productive research spending. Brazil's share of indexed scientific articles in biofuel-related fields substantially exceeds the country's world share of all scientific articles (Rothkopf, 2007, p.455).

Context for Firm Rivalry and Strategy. Historically the sugarcane and ethanol industries have been fragmented, consisting of individual families, some of which are very entrenched and quite powerful. Roughly 210 companies operate 368 sugar and ethanol mills with 128 sugar plants in the state of São Paulo alone (Regalado and Fan, 2007). The top ten ethanol producers control only 24% of the market, and two-thirds of the processed sugar comes from third-party suppliers (Bobovnikova and Miura, 2008, p.27). Currently, two-thirds of Brazil's mills switch between sugar and ethanol production—a vestige of government investment in flexible and financially stable plants for sugar producers (Rozenbaum, 2008, p.7).

But the competitive landscape within the ethanol cluster is evolving. Private-sector investment is focusing on larger and more efficient ethanol-only mills. Meanwhile, the industry has begun consolidating horizontally and vertically to realize economies of scale (Rubens, 2008). Vertical integration lowers feedstock-supply risk while making it easier to cover fixed costs and invest in new technologies; ethanol by-products also provide

fertilizer for sugarcane crops. Cosan recently became first ethanol producer to enter distribution business, competing with Petrobras, which has long held an effective monopoly downstream (Relagado and Fan, 2007).

This trend toward consolidation has also created several entry opportunities for foreign players. For example, as the largest vertically integrated players have needed capital, they have looked to foreign equity markets for initial public offerings (c.f. Cosan, Acucar Guarani, Sao Martinho). Furthermore, several banks and investment funds have gained direct ownership of ethanol plants or have established joint ventures with local partners; Goldman Sachs, for instance, recently invested $210 MM in the Santelisa Vale sugarcane-ethanol producer (Rubens, 2008). Certain development banks have also financed ethanol production to increase targeted exports (namely to Japan). Finally, joint-ventures are increasingly being used to develop ethanol/sugarcane technologies: Dow Chemical formed a joint venture with Brazilian Crystalslev to make polyethylene from sugarcane ethanol and BP invested $1 billion in ethanol refineries and Brazil's Tropical Bioenergy (Ibid).

Related and Supporting Industries. Primary supporting industries for bio-ethanol are sugarcane harvesting and sugar production. Brazil is the world largest sugar producer and exporter, with 37% world export share (Bobovnikova and Miura, 2008, p.11). In 2007 two-thirds of Brazil's sugar production was exported and one-third was consumed domestically (Rozenbaum, 2008, p.8). Since only 0.6% of Brazil's arable land is devoted to sugarcane production, the country has significant opportunity to expand to meet increased demand (Rothkopf, 2007, p.512). Approximately 55% of the sugarcane harvested this year will be directed to the production of ethanol.[21]

Brazil's sugar industry is also highly productive. Sugarcane yield per hectare increased by 33% between 1975 and 2000, and sugar content of cane increased by 8% in the same time period (Xavier, 2007, p. 10). Although most of Brazil's sugar producers can switch between sugar and ethanol production, ethanol production is frequently the more attractive choice because the global sugar industry is highly protected and plagued with overproduction.

[21] "Produção de álcool e de açúcar baterá recorde em 2008, prevê Conab", Folha Online, April 29, 2008, http://www1.folha.uol.com.br/folha/dinheiro/ult91u396881.shtml, accessed March 2009.

While the sugarcane inputs and bio-fuel outputs are commodities, the ethanol value chain also involves higher value, globally competitive industries such as industrial equipment manufacturing, chemicals and biotech companies, and flex-fuel vehicles. Specialized manufacturing equipment, particularly equipment that can resist corrosive processes, is necessary to produce sugar and bio-ethanol. Brazil's manufacturing cluster currently exports 3.0% of the world's share in farm machinery and 0.6% of the world's share in food products machinery.[22] Several multinational agricultural companies—e.g. John Deere, New Holland, Case IH—have factories in Brazil.[23] Meanwhile, local farm machinery and bio-ethanol equipment makers, namely Santal and Dedini, also compete globally.[24] In addition to Dedini's 800 ethanol plants in Brazil, it has installed 17 ethanol plants outside the country (Rothkopf, 2007, p.473).

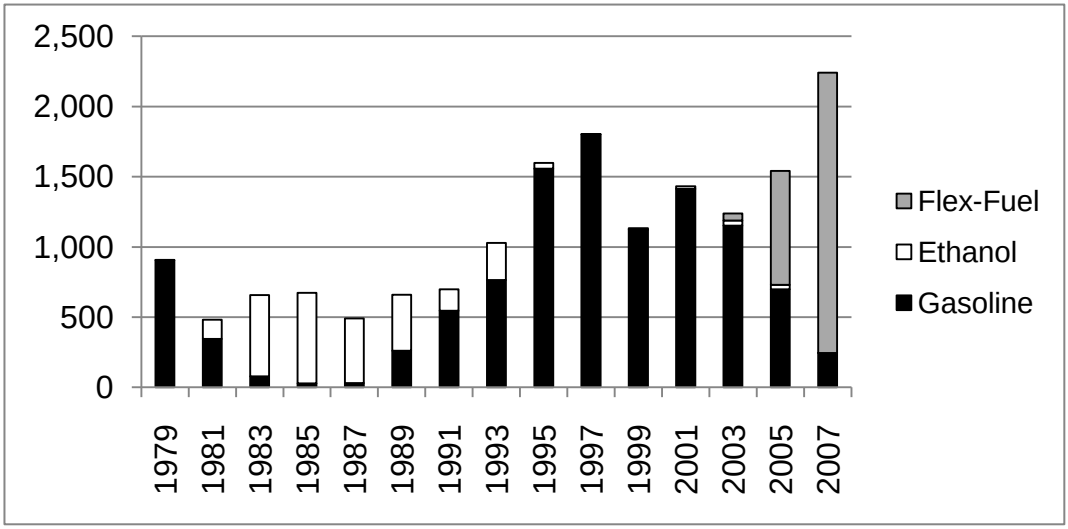
The chemical cluster supplies the bio-ethanol cluster with pesticides, catalysts, and materials. Major players include multinational corporations such as Dow, Monsanto, and Syngenta.[25] Brazil exports 1.5% of the world's share of pesticides and other agricultural chemicals and 1.1% share in organic chemicals.[26] The chemical cluster also feeds into the biotechnology cluster as chemical companies expand their capabilities into life sciences. Multinational corporations (e.g. Monsanto, Bayer Crop Science) and domestic firms produce improved crop seeds and biology-based processing technology. Two domestic firms, Canavialis and Alellyx, have developed over 21 varietals that represent 60% of the sugarcane grown in the south-central region of Brazil (Rothkopf, 2007, p.469).

The automotive engine cluster within Brazil created the first 100% ethanol automobile in 1979, the Brazilian Fiat 147 (Lemos, 2007). The construction of this vehicle built on a long tradition of vehicle construction in Brazil that began in the 1950s. But the real technological breakthrough for the ethanol cluster came in 2003, with the introduction of the flex-fuel engine. Previous ethanol cars had required the consumer to decide upon purchasing the vehicle that he was going to use ethanol and not gasoline, since the engines were constructed to run on pure ethanol fuel. Opting for ethanol frequently proved to be a suboptimal decision—

[22] International Cluster Competitiveness Database, accessed March 2009.
[23] Santal Company Web site. http://www.santal.com.br/v_Ingles/Conteudo/Empresa.htm, accessed March 2009.
[24] Ibid.
[25] Dow AgroSciences Brazil Company Web site, http://www.dowagro.com/br/index.htm, accessed March 2009. Monsanto Brazil Company Web site, http://www.monsanto.com.br/, accessed March 2009. Syngenta Brazil Company Web site, http://www.syngenta.com.br/website/default.aspx, accessed March 2009.
[26] International Cluster Competitiveness Database, accessed March 2009.

namely when oil prices fell, making gasoline more competitive, and on cold days, when the ethanol engine required a lengthy warm up.[27] By contrast, the flex-fuel vehicle (FFV) gave the consumer the ability to choose between fuel sources at the pump. FFV engine fuel sensor technology enables engines to run on any combination of ethanol and gasoline up to 100% ethanol. In 2008 FFV represented 88% of total Brazilian car sales and over 49 vehicle models (Figure 4). Many foreign engine manufacturers, such as Delphi, have regional operations in Brazil, and Brazil enjoys a 2.5% world export share in engines.[28]

Figure 4. New Vehicle Sales by Fuel Type in Thousand units[29]



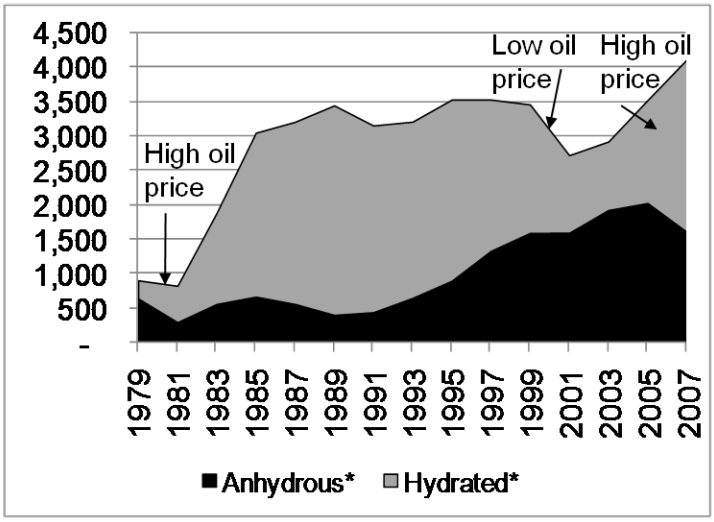
The bio-ethanol cluster also fosters innovation in the related electric power generation industry. Sugarcane producers actually generate more electricity than what is used through the burning of sugarcane bagasse in the bio-ethanol production process, called co-generation (e.g. generating both bio-ethanol and electricity). Per a law passed in 1996, this additional electricity can be sold to back to the power grid. In 2006 about 2% of Brazilian electricity (8.36GWh) came from bio-ethanol plants (Rozenbaum, 2008, p.16).

Demand. Domestic consumption of ethanol has grown dramatically since the 1970s. In 2007 ethanol consumption was 4.1 billion US gallons, equivalent to 50% of Brazil's traditional gasoline market (Giannetti Da Fonseca, 2008, p. 8). Currently, 23% of the Brazilian car fleet is flex-fuel and another 5% is ethanol-fueled

[27] Personal interview with ethanol expert, Caio Carvalhal, April 3, 2009.
[28] International Cluster Competitiveness Database, accessed March 2009.
[29] Brazilian Sugarcane Industry Association UNICA, "Brazilian Light Vehicles Sales by Fuel Type", UNICA Web site, http://english.unica.com.br/dadosCotacao/estatistica/, accessed April 2009.

(Rozenbaum, 2008, p.9). The ready availability of ethanol at retail stations and the ability of consumers to purchase flex-fuel vehicles at price parity with traditional gasoline-engine cars have enabled consumption to grow despite fluctuating oil prices. Domestic demand is also driven by the country's large population, expansive territory, and poor alternative means of transportation. The relatively low level of average income in Brazil also creates stickiness among automobile owners to hold onto their vehicles, extending the lifecycle for ethanol cars.[30]

Figure 5. Brazilian Consumption of Ethanol in Millions of US liquid gallons (Brazilian Energy Balance 2007, p. 66)



* Anhydrous ethanol is mixed with gasoline; hydrated ethanol (E100) completely substitutes gasoline

On the other hand, major constraints to domestic ethanol demand include poor roads, which make vehicle-use less attractive, and the low income level, which reduces vehicle ownership. In Brazil there are 170 vehicles per 1000 people compared to developed countries where there are 580-800 vehicles per 1000 people (2004).[31]

Meanwhile, foreign demand for bio-ethanol is limited. In 2007 global ethanol demand represented only 2.5% of the 350 billion gallon global gasoline market. Less than 10% of the global ethanol production is traded, and Brazil exports 90% of these traded volumes, mostly to the EU, the US, the Caribbean, and Japan.[32] This

[30] Personal interview with ethanol expert, Caio Carvalhal, April 3, 2009.
[31] World Development Indicators database, accessed March 2009.
[32] Calculations based on Renewable Fuels Association (RFA), "2007 World Fuel Ethanol Production", RFA Website, http://www.ethanolrfa.org/industry/statistics/#E, accessed March 2009; Brazil Ministry of Agriculture, "Brazilian Ethanol Exports Year 2007 by Country", Ministry of Agriculture Website, http://www.agricultura.gov.br/pls/portal/docs/PAGE/MAPA/ESTATISTICAS/COMERCIO_EXTERIOR_BRASILEIRO/EXP_ALCOOL_2007_PAIS.PDF, accessed March 2009.

global market dynamic reflects the fact that the market is still quite young and most consuming countries encourage domestic production of ethanol rather than imports.

Tightening environmental standards and the desire to reduce dependence on oil stands to increase Brazil's exports of ethanol in the future. However, many barriers are in place. First, import tariffs in the largest consumer markets are substantial. The US tariff is US$0.54/gallon (Budny and Sotero, 2007, p. 3) and the EU tariff is US$0.49/gallon (Tokgoz, 2009, p. 3). Additional non-tariff barriers include a lack of common international standards in ethanol chemical composition, concentration and processing. Finally, many potential markets lack necessary supporting infrastructure and complementary goods; for instance, the number of ethanol stations per million people is 174 in Brazil[33] versus 6 in the US[34] and less than 6 in the EU[35]. Fortunately, flex-fuel vehicles are available in the US and the EU at comparable prices to traditional engine vehicles; however, with the large existing base of cars (the US fleet is roughly 7x that of Brazil), transforming the existing car fleet in these developed markets is a challenging and lengthy process.

Cluster Development: Institutes for Collaboration.

Government. The ministries at the forefront of bio-fuels development are the Ministry of Science and Technology (MCT) and Ministry of Agriculture, Livestock and Supply (MAPA). MAPA oversees two critical groups operating that have ensured the development of the cluster: the Brazilian Agricultural Research Corporation (Embrapa) an agricultural research body and Agribusiness Council (CON SAGRO), an organization that collaborates with the Brazilian Agribusiness Association and smaller local organizations (Rothkopf, 2007, pp.455-56).

In 2005 MAPA launched the National Agroenergy Plan to coordinate and develop research and technology for agroenergy. This effort, led by the National Agroenergy Consortium, involves key ministries, the private sector, and research institutions.[36] The group has developed short and long term goals to advance the industry.

[33] Calculations based on Budny and Sotero, 2007, p. 6.
[34] Calculations based on US Department of Energy, "Alternative Fuels & Advanced Vehicles Data Center. Alternative Fueling Station Total Counts by State and Fuel Type", US Department of Energy Web site, http://www.afdc.energy.gov/afdc/fuels/stations_counts.html, accessed May 2009.
[35] "Bioethanol Stations European Union", Wikipedia, http://en.wikipedia.org/wiki/Ethanol_fuel#Europe, accessed April 2009.
[36] The partners in the consortium are Embrapa, the Brazilian development bank BNDES, the Bank of Brazil, and Itaipu Binacional, a hydroelectric complex owned jointly by Brazil and Paraguay.

Non-Profit Groups. As early as 1948, non-profit organizations have been dedicated to the technological and scientific advancement of the country; the Brazilian Society for the Progress of Science brought together groups of academics, students, professionals, and trade associations. Forty years later, the Brazilian Society of Biotechnology was formed to help advance biotechnology efforts in the country. Following it in 1998 was the launch of the National Biosafety Association (ANBio), which is focused on protecting biological diversity.

Business Groups. An early enabler of the cluster was Petrobras, which previously provided a guaranteed market for ethanol and still distributes and markets bio-ethanol products. Petrobras has spent over US$400M in R&D via its organization, The Leopoldo Americo Miguez de Mello Center for Research (CENPES) (Rothkopf, 2007, p.464). Meanwhile UNICA, a major union of sugar and ethanol producers representing 60% of total Brazilian ethanol production, serves as a national information center, lobbies for producers, and maintains state-level representation (Rothkopf, 2007, p.471).

Universities. The University of Rio de Janeiro and the State University of São Paulo are the most widely known and best funded educational institutions with specialization in bio-fuels. The University of Rio de Janeiro is a member of the University Network for Sugar-Ethanol Development (RIDESA) that coordinates R&D on sugarcane-derived ethanol through seven federal universities and 12 experimental sites across Brazil. Similarly, the State University of São Paulo is home to the Clean Technology Development Laboratory, which studies bio-diesel technologies, and the Brazilian Reference Center on Biomass, which is advancing the use of sugarcane bagasse for cogeneration. Also active the State University of Campinas, which is developing new sugarcane varietals and processes to improve bio-fuel efficiency; the university also houses an innovation incubator that has spun off 22 companies (Rothkopf, 2007, p.469).

Cluster Performance.

Brazil is the second largest producer and the largest exporter of bio-ethanol. In 2007 the country produced and consumed 5 billion[37] and 4.1 billion gallons of ethanol, respectively (Giannetti Da Fonseca, 2008, p. 8). Brazilian sugarcane ethanol has significant performance advantages over other forms of ethanol. First, the

[37] Renewable Fuels Association (RFA), "2007 World Fuel Ethanol Production", RFA Website, http://www.ethanolrfa.org/industry/statistics/#E, accessed March 2009.

energy conversation from sugarcane feedstock is four-times higher than from wheat, beet sugar, or corn (Wright, 2008, p. 7). Second, production costs associated with Brazilian ethanol are ~$0.80/US gallon compared with ~$1.30/ US gallon for US corn and ~$1.70 for EU wheat or beet sugar (Budny and Sotero, 2007, p. 5). These performance advantages reflect Brazil's commitment to investment in sugar varietals and efficient process manufacturing.

Strategic Issues & Recommendations

Country level.

Informal economy and embedded corruption. *Officials should mandate and enforce transparency and governance by creating a federal Office of the Ombudsman to monitor and punish cases of corruption. Federal and state governments should follow examples set by Porto Allegre and São Paulo in establishing participatory budgeting, streamlining laws, and strengthening law enforcement.*

Significant trade barriers. *The Ministry of Development Industry and Trade (MDIT) should target eliminating remaining import tariffs over the next five years.*

Difficulties in obtaining credit and high interest rate spread. *A centralized, digitized registry should be created to improve the documentation of collateral and recognition of property rights, particularly among poorer segments of the population. This measure will reduce the risk for the lenders and result in lower lending interest rates and greater availability of credit.*

High tax burden. High tax burden in Brazil is partly caused by the government's determination to conduct orthodox fiscal policy with primary fiscal surpluses. However, the same goal can be achieved at a lower level of both tax revenue and government spending. *To reduce government spending, the national budgeting office should engage external experts to identify line items that can be eliminated from the budget. External mediation may be necessary, to broker negotiations between the government and unions as well as other powerful interest groups lobbying for pork spending. As a following step, the tax system should be reformed to reduce both the tax burden and the complexity of paying taxes. This measure will also help reduce the informal sector of the economy.*

Poor quality of education. *The budget should immediately increase public funding for science-related higher education. The Ministry of Education should be charged with increasing enrollment in tertiary schooling through better outreach and work-study programs.*

Cluster level.

Factor Inputs.

Low quality and low density domestic transport infrastructure and port facilities. *The President should create a federal development fund to support public and private partnerships investing in ethanol pipelines and the expansion of critical infrastructure such as roads, railways and waterways. Proposals should be reviewed on a priority basis with a three-week turnaround.*

Lack of qualified personnel for high-end research. *The National Council for Science and Technology Development and São Paulo State Government Bio-fuel Chamber should be tasked with developing industry-specific training and allocating graduate level scholarships in the sciences.*

Context for Rivalry and Strategy.

Weak coordination between public and private sector. *Embrapa, a ministerial research organization, should serve as the coordination mechanism for public and private R&D. The Trade & Investment Promotion Office should actively recruit foreign players to participate, particularly in the higher value-added segments.*

Demand Conditions.

Sensitivity of demand to changes in the oil price. Brazil currently enjoys a cost-advantage in producing ethanol, but this assumes oil is priced at least $35/barrel. *Brazil should continue to reduce costs by developing domestic and export transportation infrastructure and by increasing R&D to boost agricultural productivity and processing efficiency.*

Uncertain commitment to bio-fuels in major consuming markets. The food versus fuel debate has created further hesitancy over the global adoption of biofuels. *While President Lula already has been vocal about sugarcane ethanol's limited impact on arable land, the government needs to better educate global consumers about the advantages of sugarcane ethanol, particularly vis-à-vis less efficient feedstocks, such as corn, which*

does compromise the food supply. [38] *Top Brazilian officials should use major public forums to promote global bio-fuel use. The Trade & Promotion Office should launch a green PR campaign pushing for usage of the lowest cost and most energy efficient feedstock. Brazilian policymakers, researchers and industry participants should share expertise with major consumer nations on how to increase the use of ethanol.*

Limited international demand due to import tariffs and non-tariff trade barriers. US tariffs on Brazilian ethanol increase its cost by ~ 50%. *Brazilian trade officials should work through the WTO, in concert with the Mercosur and Andean trade blocs, to insist that their trade partners reduce bio-fuel tariffs and non-tariff trade barriers. The President and top ministers should continue to broker memorandums of understanding with foreign partners to increase ethanol exports and advance cooperative bio-fuels research.*

Related and Supporting Industries.

Risk of competition from cellulosic ethanol (and other future generation) technologies. Thus far the cluster thus far has upgraded primarily through investments in R&D to develop new sugarcane varietals and improved ethanol production processes; this has continued to bring production costs down and improve productivity of Brazilian sugarcane ethanol. Additional investment in alternative high-energy feedstocks (e.g. soy oil) will further advance the cluster. Since most R&D for the cluster has come from the private sector, government stands to play a more active funding role through various mechanisms such as matching programs for private investments. *The Ministry of Science and Technology (MCT) should allocate a fixed percentage of its budget to primary research focused on advanced multi-feedstock bio-fuels. The MCT should also help universities and university networks (such as RIDESA, the University Network for Sugar-Ethanol Development) to pool knowledge and incubate new businesses in next-generation alternative fuels.*

Avoid keeping Brazil "stuck in the commodity game". Although ethanol production begins with commodity inputs and results in commodity outputs, the supply chain involves several higher-valued added sectors. These businesses are capable of serving not only the bio-ethanol industry, but a variety of high-value industries, namely pharmaceuticals, specialty materials and chemistry, advanced engines and turbines. *The Ministry of*

[38] "Brazil's Lula: ethanol no threat to food supply", Thomson Reuters, April 16, 2007, http://www.reuters.com/article/environmentNews/idUSN1628734720070417, accessed March 2009.

Development Industry and External Trade (MDIC) should attract established international pharmaceutical and biotech companies to leverage scientific capabilities in plant genomics and engineering and enable the exportation of flex-fuel technologies and related products. MDIC should assist universities and university networks to undertake collaborations with leading academic institutions and organizations outside Brazil that focus on plant biology, food process and engineering, and engine technologies. President Lula should champion a bio-ethanol cluster strategy for Brazil, engaging federal and state governments, the nexus of relevant IFCs, as well as domestic and foreign industry players. Focused efforts of industry, research and government would upgrade the cluster, advance the bio-fuel industry, and increase the competitiveness of the Brazilian economy.

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