Vertical integration in a growing industry: security of supply and market access in fuel-ethanol value chain

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Abstract

The global bioethanol industry has been expanding rapidly with an average growth rate of 15% annually during the past decade. We focus on the top 30 global manufacturers and 10 additional regional/national firms and identify three fundamental forces which drive the evolution in the industry structure: (i) the permeability of the industry boundaries, (ii) security of supply and (iii) access to market.

The permeability of industry boundaries is very high as entry is common from neighbouring industries. Five main groups of players have been identified in the manufacturing segment: (i) oil & gas industry, (ii) commodity traders, (iii) technology suppliers including engineering and biotech, (iv) traditional food and beverage processing & farmer cooperatives, and (v) new entrepreneurial start-ups.

There has been a strong horizontal consolidation and vertical integration across the industry value chain. The prime motivation to migrate upstream is to secure supply and mitigate risks of price volatility. Oil and gas firms move upstream to enhance security of supply while the commodity and food firms migrate downstream towards production and retailing to gain market access. We explain this trend in terms of major theories of the firm and propose a more comprehensive view of the firm, taking economic, social and environmental factors into consideration.

Keywords:

Bio-ethanol, Biofuel, Ethanol, Governance, Industry evolution, Value Chain, Vertical Integration

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Introduction

The global bio-ethanol industry has expanded rapidly in the past decade, increasing at an average annual rate of 15%[2]. About 80% of the production is supplied to the rapidly growing fuel-ethanol market and the rest is for the rather stable demand in the industrial and beverage sectors. Fuel-ethanol, as an additive/substitute for gasoline in otto-cycle transport fuel market, is gaining substantial market share, especially in Europe, North and South America and reached about 6% of the global gasoline fuel market in 2009[3].

Bio-ethanol, or biofuels in a broader sense, has attracted substantial policy research. There is a growing body of literature related to biofuels, which has been primarily focused on policy instruments (Sorda *et al.*, 2010; Balat & Balat, 2009), environmental impacts and greenhouse gas emission reductions (Searchinger *et al.*, 2008; Kim *et al.*, 2009)), food and poverty interactions (FAO, 2009; Pfuderer & Castillo, 2008), and technology advances (Himmel and Bayer, 2009; Escobar *et al.*, 2009; Balat *et al.*, 2008). Hitherto, there has been no attempt to understand the evolution of the structure of this rapidly growing industry and the dynamics of industrial governance of the complex political and economic landscape over time.

We analyse the forces behind the evolution of the bio-ethanol industry by examining the dynamics along the entire value chain, with a particular focus on the core segment of ethanol manufacturing. The global bio-ethanol value chain can be divided into three distinct groups - the upstream agri-commodity segments, the midstream ethanol manufacturing segments, and downstream transport fuel segments. Three forces that shape the evolution of the structure of industry will be discussed in greater detail, namely: (i) permeable industry boundaries, (ii) security of supply and (iii) access to market. These forces encourage a trend towards vertical integration as observed in recent industry developments.

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[2] Calculated based on data estimated by F.O. Lichts as in Figure 3.

[3] Ethanol data based on estimation done by F.O. Lichts. Gasoline data from Euromonitor.

The impact of permeability of industry boundaries has been observed by Fransman (2001) in the study of telecommunications industry. The permeability of boundaries can be seen in the ease of entry from neighbouring industries. There are many different types of industry players with different backgrounds entering the bio-ethanol industry at various segments along the value chain, especially in the manufacturing segment. These actors include engineering companies, major oil & gas firms, agri-food processors and agri-commodity traders. These companies have their respective competitive advantages in terms of resources and experience.

The second driving force is security of supply. There are two important supply points along the value chain - supply of feedstock for ethanol production and supply of ethanol for gasoline blending. The majority of ethanol manufacturers face substantial risks in feedstock supply and price volatility. In many countries, ethanol is neither the primary market nor large enough to have influence on pricing of major feedstocks. This has created a propensity towards upstream integration in the industry, but the degree of integration from market to market has been strongly influenced by the local and national political economy of feedstock production and supply markets. On the other hand, upstream integration to manufacturing segment to secure ethanol supply has been relatively easier and politically less sensitive. Therefore, a stronger wave of integration is observed in this segment.

The third dynamic that shapes the industry structure is access to market. There are three markets along the value chain. The first market is the market for feedstock. Feedstock manufacturers and traders integrate downstream to access a stable feedstock market supplying ethanol manufacturers. Another motivation may also be pursuit of additional downstream rents. The other two markets – ethanol and retail fuel – are closely linked. The size of the ethanol market is linked to the retail fuel market for ethanol. There are mainly two segments - low blend (E5 or E10) and high blend (E85 or

E100)[4]. The low blend market is highly regulated in all markets: governments have created markets for ethanol blending but also have limited the expansion of these markets by putting a cap on the maximum blending ratio. In the high blend market, ethanol manufacturers integrate upstream to gain market access because it is a niche market where petroleum refiner has little market power.

This fast-growing ethanol industry with its special characteristics of crossover from agricultural value chain to energy value chain provides a different evolution patterns and dynamics in the formation of industrial structure. Working together with other economic factors, these three fundamental forces have shaped the structure of bio-ethanol industry. We observe not only the creation of giant horizontally consolidated firms but also evidence of increasing vertical integration.

In this paper, we first provide a description of the core segments in the value chain of the industry. The second section describes the degree of horizontal concentration in the ethanol manufacturing segment on a global scale. The top 20 manufacturers are ranked and their market shares are estimated. Concentration ratios are also calculated and discussed.

Section three examines the vertical integration of the top 30 global firms and 10 other major regional or national firms in the manufacturing segment of the value chain. A classification of the manufacturers is proposed based on their sectoral background. The fundamental forces that shape the structure of industry and the drivers of vertical integration in both directions in the industry will be discussed.

Finally, a discussion is offered to compare the empirical reality of ethanol industry with various theories of vertical integration. We propose that a wider perspective to include socio-political factors into the analysis of governance structure is important to understand the trends in this new and fast growing fuel-ethanol industry.

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[4] E denotes ethanol. E5 is 5% ethanol content in retail gasoline. Low blend ethanol-gasoline is marketed to existing car mostly without any requirement for engine modification. Government regulates the percentage of blending and quality to protect consumer's right. High blend ethanol-gasoline serves a niche market – new car designed to run specifically for the blending ratio.

Bio-ethanol Value Chain

Bio-ethanol value chain is created by a crossover of two value chains, i.e. the agri-commodity value chain and energy value chain as depicted in **Figure 1**. The upstream of the industry is the traditional agricultural value chain consists of three segments - the land, cultivation, and trading and transporting of agricultural produces. The midstream consists of ethanol manufacturers and traders with an auxiliary segment, which is not a segment along the main value chain, for technology, chemicals, yeast, enzymes, and utility suppliers. The downstream is similar to the conventional transport fuel downstream chain, where ethanol is blended and distributed to retail transport fuel stations.

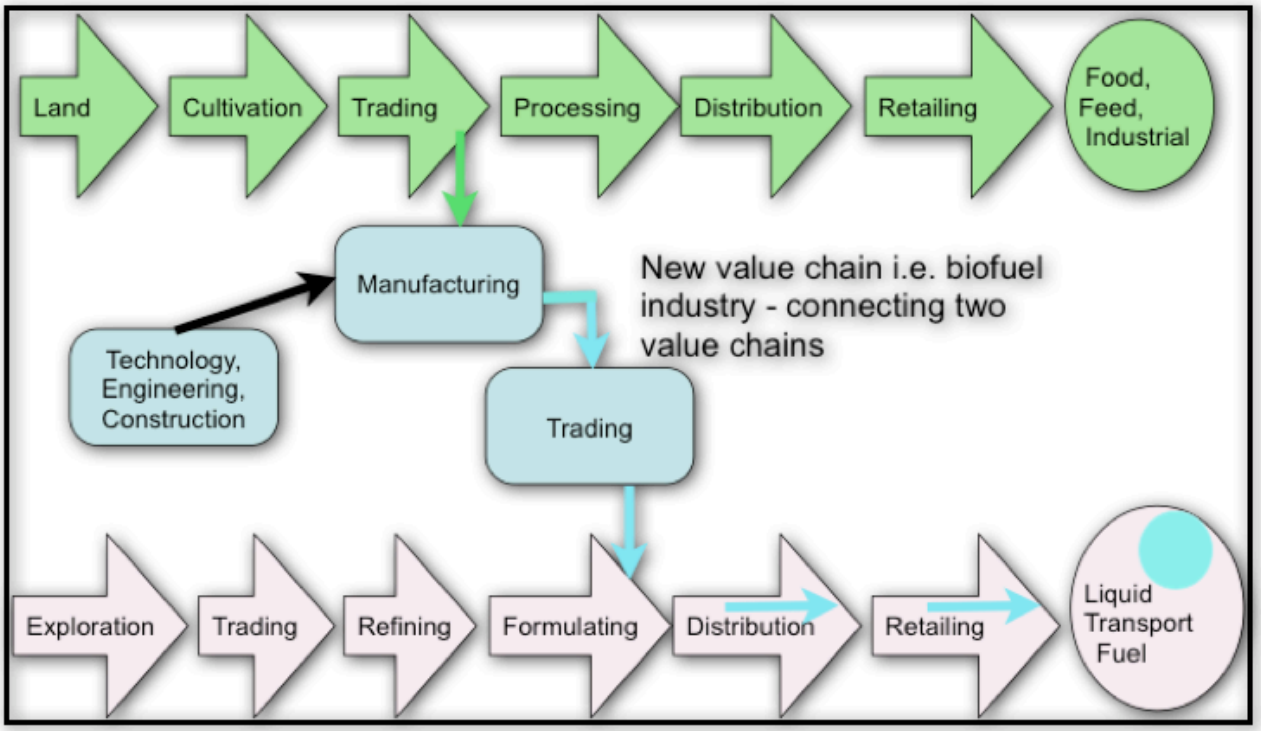

Figure 1: Bio-ethanol Value Chain: Cross over of Agri-commodity Chain to Energy Chain
Sources: Authors

There are a several different agricultural feedstock used for the production of bio-ethanol. **Table 1** shows the main feedstock used in major producing countries. The traditional feedstock are sugarcane and beet molasses used for the production of beverage and industrial grades alcohol in many countries prior to the existence of fuel-ethanol market. But there is an increasing use of

maize, sugarcane juice, wheat and cassava as there are many manufacturing facilities utilizing these feedstock being built in the US, Brazil, EU and South East Asia.

Table 1: Main Feedstock used in major Producing Countries

	Country/Region	Main Feedstock
1	USA	Maize
2	Brazil	Sugarcane, Cane Molasses
3	EU	Beet, Beet Molasses, Wheat, Maize
4	China	Maize, Wheat, Cane and Beets Molasses, Cassava
5	India	Sugarcane Molasses
6	Canada	Maize
7	Thailand	Sugarcane Molasses, Cassava
8	Columbia	Sugarcane, Cane Molasses
9	Australia	Sugarcane Molasses

Sources: Authors

The overall percentage of feedstock production used for bio-ethanol production has been relatively low compared to that for other uses as shown in **Figure 2**. Therefore, the ethanol market has a relatively weaker impact on the price of feedstock compared with other markets for the feedstock. For example, the sugar cane price is very much correlated with sugar price rather than ethanol price in many countries such as Thailand and the Philippines. Cassava price in Thailand is linked to export market rather than the domestic ethanol price.

Due to uncertainty in feedstock supply and price volatility, manufacturers are inclined to integrate upstream to mitigate risks. In the US, those manufacturers without a certain degree of upstream integration are susceptible to feedstock risk. For example, Verasun, once a leading ethanol manufacturer hedged maize in the future market. On 31 October 2007, Verasun had to seek bankruptcy protection after a drop in the maize futures market. On the other hand, the other two top ethanol manufacturers - AMD and POET escaped the fate of Verasun by having had a stronger degree of integration upstream to trading and cultivation of maize.

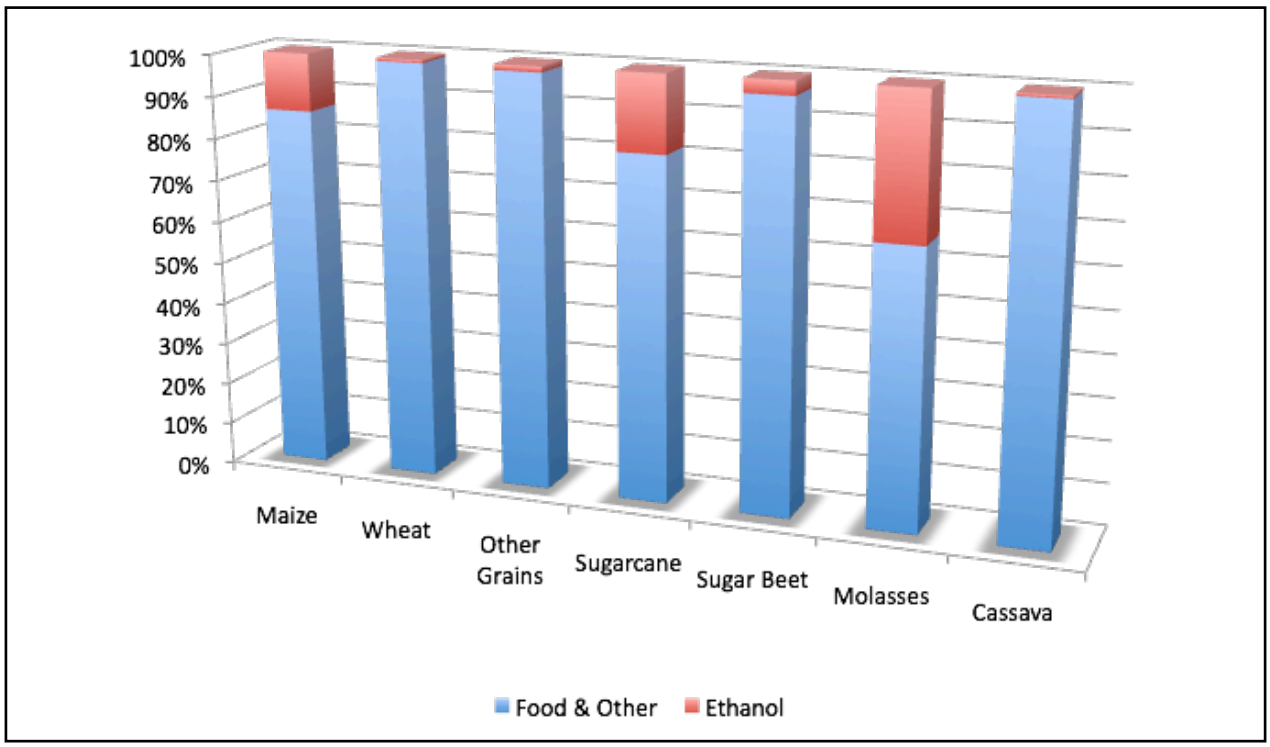

Figure 2: Percentage of Various Agricultural Produces used for Bio-ethanol Production
Sources: Authors, data from F.O. Licht's Vol. 7 No. 5, 2008 and FAO Online Statistics on Agricultural Products 2009

The midstream manufacturing segment is the core segment of the ethanol industry and is the main indicator of growth in the industry. **Figure 3** shows global bio-ethanol production from 1975 to 2009. Total world ethanol production nearly tripled in the last decade, reaching 87.26 billion litres in 2007, increasing from 32.17 billion litres in 1988. The USA and Brazil are the leading bio-ethanol manufacturers with 47% and 31% of global production respectively in 2009. Other major producing countries include European Union (6.8%), China (5.1%), India (2%), Canada (1.3%), Thailand (0.8%), Columbia (0.4%) and Australia (0.3%). Production is expected to increase in the next few years not only in the USA and Brazil but also across many countries in Latin America, Africa and Asia because distilleries will be coming on stream due to expansion in investment and markets driven by both favourable policies and competitiveness as a gasoline substitute.

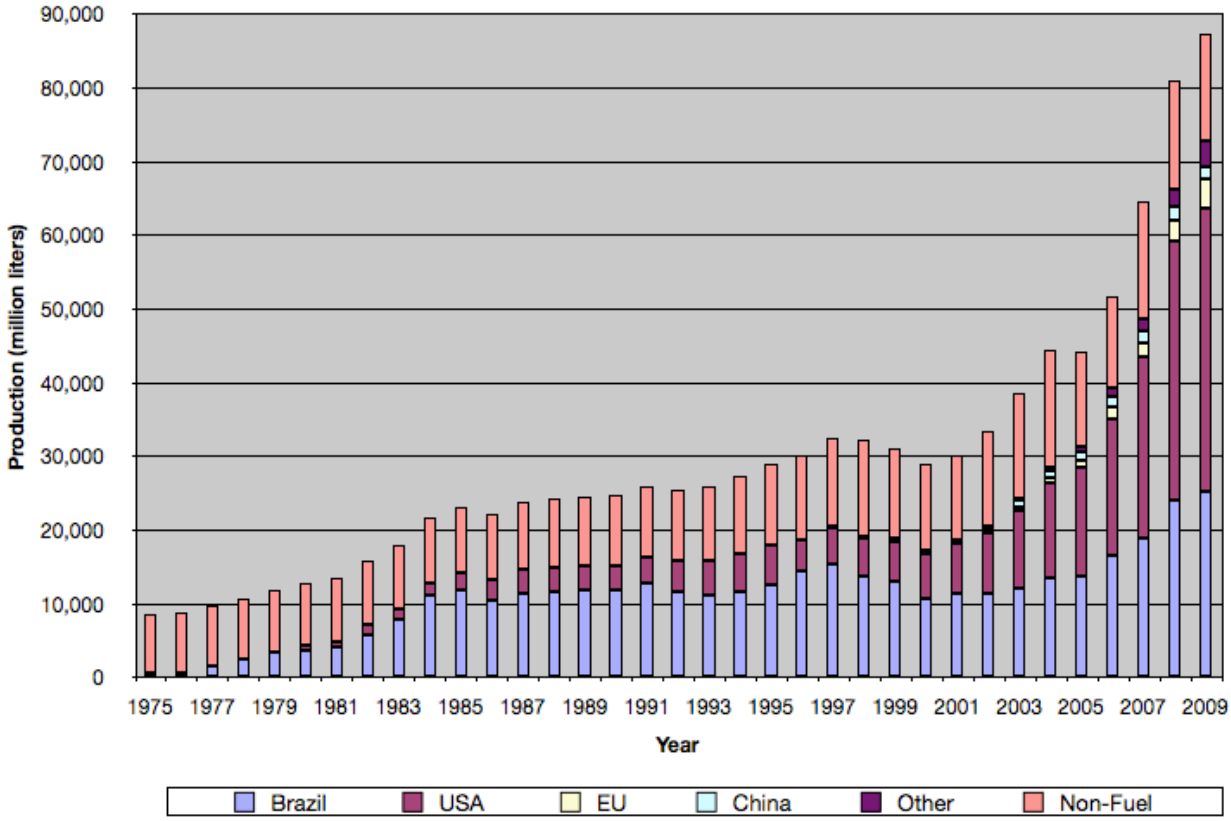

Figure 3: Global Bio-ethanol Production, 2009
Sources: Date calculated from estimation of World Ethanol and Biofuels Report, 6(4) 2007 & 8(16) 2010 F.O. Lichts.
Note: Fuel ethanol production by countries in colour coded bars. The top series is global non-fuel ethanol production. Non-fuel production prior to 1998 is extrapolation.

Figure 4 shows the market cycle of the bio-ethanol industry. It is currently in the Growth stage with rapid increase in market penetration. Nevertheless, the potential for further growth depends on a number of factors such as land and feedstock availability and price, the price of oil, sustainability government policies, and possible technological breakthroughs. There are many government, research institutes and private companies, which have begin to invest heavily in 2nd generation fuel-alcohol research. A breakthrough could have a disruptive effect on the production processes and feedstock requirements as well as pushing the market penetration of ethanol much further.

For the downstream segment, the majority of bio-ethanol produced is to supply the rapidly expanding fuel-ethanol market. In 2009, about 84% (73 billion litres) of bio-ethanol was produced for fuel-ethanol market compared to 60% a decade ago. On the other hand, the beverage and industry markets are relatively stagnant, fluctuating between 13 and 16 billion litres as shown in **Figure 3**.

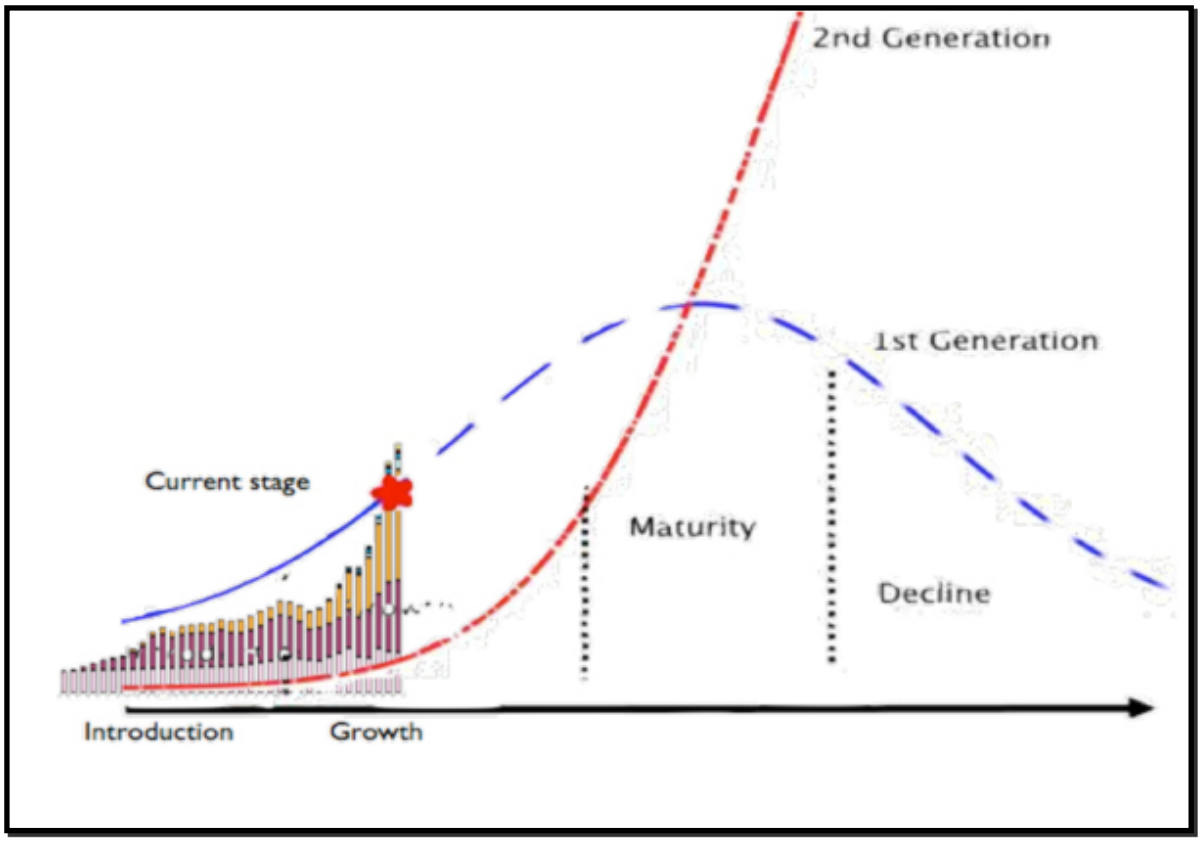

Figure 4: Bio-ethanol Market Cycle
Source: Authors

The majority of fuel-ethanol produced serves domestic markets. Brazil is the main exporter but it only exported 13% of the 25.2 billion litres it produced in 2009. The two major importers are the US and EU. Other major importing countries are Japan, South Korea and Canada.

The bio-ethanol share in global oil supply was about 1.4% in 2009. For otto-cycle transport fuel, ethanol contributed 5.7% by volume. The USA consumed 42 billion litres of fuel-ethanol, which was about 7.4% by volume of total motor gasoline followed by Brazil (22.65 billion litres), which amounted to over 55% by volume of total motor gasoline. The EU27, China, Canada and Thailand respectively consumed 4.2, 1.7, 1.5 and 0.46 billion litres as shown in **Table 2**.

Fuel-ethanol is increasingly penetrating into gasoline markets as a substitute. Market share is very much dependent on government targets and mandates but it also varies with the relative price of ethanol to gasoline. There are other factors that could increase or be barriers to the expansion of ethanol market share, which will be discussed in later sections.

Table 2: Estimation of Ethanol Share in Otto-cycle Transport Fuel in 2009

Country	Gasoline (million litres)	Ethanol (million litres)	% Ethanol by Vol.
Global	1,227,000	74,443	5.7%
USA	524,444	42,026	7.4%
Brazil	18,462	22,650	55.1%
EU	131,500	4,187	3.1%
China	72,730	1,730	2.3%
Canada	40,853	1,500	3.5%
Thailand	7,063	460	6.1%

Source: Gasoline data based on Euromonitor, Ethanol data based on US EIA & F.O. Lichts

Horizontal Consolidation in the Ethanol Manufacturing Segment

Over the last decade, there has been a strong trend towards merger and acquisition in the global ethanol manufacturing segment. We estimate the market concentration for the global ethanol manufacturing segment and to identify top global and regional manufacturers. The global concentration ratios are also calculated based on simple four-, eight- and twenty-firm ratios.

The measure of market share is based on nameplate production capacity of each manufacturer. Production capacity includes the design capacity at the year of interest, the capacity of new plant and expansion of existing plants under construction as of 2009. Since ethanol is an undifferentiated commodity a firm's capacity is likely the best measure of its competitiveness.

A plant/distillery's capacity is not a good indicator for most of the manufacturers in Brazil however since the distillery is normally an integral part of a sugar mill in Brazil. The mill adjusts the ratio of sugar to ethanol based on the prices signal of both commodities. So for Brazil actual production data is used.

In addition, there is no data available on total global production capacity. The denominator of the measurement of concentration is based on actual global production of bio-ethanol in 2009. Therefore, estimates of market shares and concentration ratios are on the high side.

Table 5: Top 20 Global Manufacturers in 2009 (CR4=25.0, CR8=34.3, CR20=49.3)

No	Holding Company	HQ Location	Main Ethanol Producing Location	Production/Capacity (million litre/year)	Global Share(%)
1	ADM	USA	USA	6,937	7.95%
2	POET	USA	USA	5,957	6.83%
3	Valero	USA	USA	4,806	5.51%
4	Abengoa	Spain	USA/EU/Brazil	4,094	4.69%
5	Cosan	Brazil	Brazil	2,468	2.83%
6	Shree Renuka	India	Brazil/India	2,020	2.31%
7	GPRE	USA	USA	1,860	2.13%
8	ETH Bioenergia	Brazil	Brazil	1,748	2.00%
9	Hawkeye	USA	USA	1,628	1.87%
10	Bunge	USA	Brazil	1,486	1.70%
11	Tereos	France	France/Brazil	1,415	1.62%
12	Louis Dreyfus	France	Brazil	1,364	1.56%
13	Andersons	USA	USA	1,066	1.22%
14	White Energy	USA	USA	1,000	1.15%
15	Pacific Ethanol	USA	USA	961	1.10%
16	COFCO	China	China	925	1.06%
17	Biofuel Energy	USA	USA	891	1.02%
18	Tate&Lyle	USA	USA	814	0.93%
19	Glacial Lake Energy	USA	USA	802	0.92%
20	Aventine RE	USA	USA	802	0.92%

Note: Information and ranking is based on data and information as of March 2010.
Source: Authors.
The data used is from publicly available information. The Renewable Fuel Association (RFA) of the USA publishes annual production capacity for each manufacturer, capacity expansion and new plant under construction. The Brazilian Sugarcane Industry Association (UNICA) publishes annual ethanol production of manufacturers in Brazil. Other sources of data include public announcements, industrial magazines, and manufacturers' websites, which provide information on the capacities and expansion/construction plans.

Table 5 shows the top 20 global bio-ethanol manufacturers in 2009. The top three manufacturers are all American domestic players, i.e. ADM, POET, and Valero, controlling 7.95%, 6.83% and 5.51% respectively of global market share. The American agribusiness giant, Archer Daniels Midland Co. (ADM) bought the Minnesota Maize Processors, the then 3rd largest ethanol manufacturer in 2002, increasing its total capacity to 4.15 billion litres of ethanol. As a result of continued expansion and building new facilities, ADM is the largest manufacturer in the US (11%) and the world (7.9%) in 2009.

POET comes second with 6.8%. Even through POET does not have controlling equity stake in all its name-plated distilleries, it expands rapidly in the last 5 years especially in managing facilities

and marketing ethanol. Valero, the oil refiner, becomes the third largest manufacturer by acquiring assets from bankrupted firms, mostly those of Verasun in 2009.

Some ethanol manufacturers operate across several regions. The best example is Abengoa Bioenergy, which has significant presence in the manufacturing segment on the three most important continents for ethanol production and consumption i.e. USA, South America and Europe. Total installed capacity is expected to reach 4.1 billion litres by 2010. It is the 4th largest manufacturer in the world with a 5.5% market share.

Cosan SA Industria e Comercio, the world's largest sugarcane processor and the largest ethanol manufacturer in Brazil is in 5th place globally with a 2.83% global share. As of 2009, Cosan owns 23 cane processing plants increased from 17 in 2007. The mills crushed 44.2 million tonnes of cane, about 10% of total Brazilian harvested in 2008/09 session. Cosan produced more than 2.4 billion litres of ethanol in 2009, up from 1.4 billion litres in 2007.

Shree Renuka is in the 6th place with a 2.13% share after its acquisition of Group Equipav on 21 Feb 2010 in Brazil. The second largest ethanol manufacturer in Brazil, ETH Bioenergy, is in the 8th place after GRPE (7th) of the USA. With continuous expansion and acquisition, ETH Bioenergy formed in mid 2007 is expected to have ethanol production capacity up to 1.7 billion litres by 2012.

International commodity giant, Bunge is in the 10th place after another US manufacturer, Hawkeye (9th). Bunge continues to expand with the acquisition of Moema Grupa on 11 Feb 2010. Two other international commodity giants, Tereos and Louis Dreyfus also operate in Brazil and are in 11th and 12th places respectively.

Globally, the four-firm concentration ratio is only 25% suggesting there is little oligopolistic market power in the global ethanol industry. However, if consolidation trends continue in the USA and Brazil, there is a possibility that fuel-ethanol production giants will be created, which will have significant global market power.

Vertical Integration in the Ethanol Industry

Next, we investigate the degree of vertical integration and drivers of the changes in the bio-ethanol industry structure by examining the 30 largest global manufacturers. In particular, the sectoral background of the manufacturers and their vertical involvement in the bio-ethanol value chain is investigated. In order to capture specific aspects of the integration trends, an additional 10 players in the value chain has also been selected. They are either major regional manufacturers or oil and gas corporations with involvement in the bio-ethanol chain.

These forty firms have been categorised into five main groups and colour coded in **Table 6** based on their sectoral background. These five main groups are:

i) Group 1: Technology, engineering and construction firms;

ii) Group 2: Farmer & farmer cooperatives and Agri-food & Sweetener Manufacturers, with a long history in food/sweetener production, and some in ethanol production;

iii) Group 3: Agriculture commodities traders. Their main activities are sourcing and market agriculture commodities, but some firms have diversified extensively or have been involved in food processing industry for a long time;

iv) Group 4: Entrepreneurial start-ups with minimal or no background in the supply chain;

v) Group 5: Oil and Gas firms and downstream marketers.

The columns in **Table 6** represent segments of ethanol value chain. The first two columns are for auxiliary segments of 1st and 2nd generation technology suppliers. The agri-food processing column does not belong to the fuel-ethanol value chain. It is included to show the traditional activities of some players.

Cells shaded in the colour of a firm denote that they fall within the traditional activities of that firm, whereas cells shaded in green indicate new business activities along the value chain.

Table 6: Major Players in Bio-Ethanol Value Chain, 2009

Global Rank	Firm	Eng/ Const	2nd Gen/ Enzymes	Plantation	Ag service/ Trade	Agri-food processing	Ethanol Manufacturing	Market/ Transport	Blending	Refine/ Wholesale	Retail
2	POET, US										
4	Abengoa, ES										
8	ETH Bioenergia, BR										
5	Cosan, BR										
6	Shree Renuka, ID										
11	Tereos, FR										
18	Tate&Lyle, UK										
24	Sudzucker, DE										
25	Sao Martinho, BR										
26	Cristal Union, FR										
28	PedraAgroindustry, BR										
29	Moreno, BR										
30	Zilor, BR										
	Petro Green, TH										
1	ADM, US										
10	Bunge, US										
12	Louis Dreyfus, FR										
13	Andersons, US										
16	COFCO, CN										
19	Glacial Lake Energy, US										
21	Noble, HK										
	Verasun										
7	GPRE, US										
9	Hawkeye, US										
14	White Energy, US										
15	Pacific Ethanol, US										
17	Biofuel Energy, US										
20	Aventine RE, US										
22	Jian Shenghua, CN										
23	AltraBiofuels										
27	Global Ethanol, AU										
	TPK Ethanol, TH										
	Greenfield Ethanol, CA										
	SEKAB, SE										
	Greenergy, UK										
3	Valero, US										
	CNPC/Jilin, CN										
	BP, UK										
	Husky Energy, CA										
	Shell, NL										

Note: Colour Code	
	Engineering and construction company who builds plants and supplies technology
	Farmer/farmer cooperative and Agri-food processor, with a long history in sweetener production
	Global/National agri-commodity trader
	Entrepreneurial start-up with minimum or no background in the supply chain
	Oil & Gas company, either integrated or in downstream business
	Company with liquidity problem, in insolvency or in the process of debt restrucuturing
	Involvement in a segment of the ethanol value chain

Source: Authors. Data from manufacturers' websites, RFA & UNICA statistics.

We observe that Group 1 engineering firms, are not only involved in R&D activities on 2nd generation technology but have also expanded vertically into the manufacturing and other

downstream activities of the value chain. The most vertically integrated firm in this group is Abengoa, which comes from an engineering & construction sector background, building distilleries all over the world. On the other hand, some ethanol manufacturers have also venturing into this auxiliary segment. In the USA, POET and ADM both design and build their own distilleries. A newcomer into this segment is Shree Renuka of India, which is a sugar-ethanol company based in India that has operating units in both India and Brazil. It has recently (2007) acquired KBK, an engineering and construction company based in India, which builds distilleries throughout Asia.

The traditional food processors of Group 2 are involved heavily in the ethanol manufacturing segment as this is their natural competitive advantage with a long history of knowhow in feedstock processing and sourcing. Group 2 firms enjoy a high level of security of feedstock supply although a few firms have further integrated into downstream activities. Cosan is the most vertically integrated ethanol firm in the world as seen by its involvement in every segment along the sugarcane-based ethanol value chain. In 2007, Cosan acquired ExxonMobil's downstream operation in Brazil. In early 2010, it announced the signing of an MOU with Shell to form a giant ethanol group in Brazil. The agricultural commodity traders, farmers and farmer cooperatives are also venturing into the ethanol industry, primarily in the manufacturing and marketing segments, thereby leveraging their knowledge of feedstock supply and their marketing capabilities. However, they have shied away from the downstream blending, distribution and retailing businesses.

In Group 4, these new start-ups generally have little corporate background in the ethanol industry. They entered the market because of favourable government policies for ethanol manufacturing and use in transport fuel. Some firms have moved extremely quickly to expand horizontally by raising equity in the stock market or from private equity funds. Many of these firms in both the USA and Brazil have expanded too quickly and began to face liquidity problems during the global credit crisis. A few firms in the USA have also employed a vertical integration strategy especially into the downstream in order to gain market access. For example, GPRE acquired Blendstar to penetrate

into downstream blending and distribution markets. Before its collapse, Verasun was marketing its own branded E85 fuel with 85% ethanol content, selling to a network of retailers.

The final group is oil and gas corporations. Many corporations with downstream gasoline businesses have to comply with national policies of blending ethanol and have therefore become involved in the value chain. Oil and gas firms have diverse interests in moving upstream along the ethanol value chain. Their involvement in sourcing and trading ethanol has been very substantial already. For example, Greenergy, claimed to be the top UK's road fuel supplier and have a 20% market share, is also one of the largest ethanol suppliers in the UK with extensive upstream sourcing and logistic capabilities. Shell and BP have been moving and trading large quantities of ethanol globally. BP has also claimed that it has blended and distributed 2.89 and 0.34 billion litres of fuel-ethanol in 2007 respectively in the USA and Europe, which in total is about 6.5% of the world's downstream market share in 2007. In 2008, BP has also committed to purchase and market 103 million litres of fuel-ethanol in Australia. On the other hand, Shell claimed to distribute more than 5 billion litres of ethanol in 2007. Total and Statoil both market ethanol blended fuel in their respective domestic markets.

In addition, these firms have shown interest in moving further upstream into the manufacturing of ethanol and supply of feedstock. BP has invested in 2 major greenfield projects in Brazil and a 420 million litres distillery joint venture with British Sugar and Du Pont in the UK. BP is expected to have a total installed capacity of 1.42 billion litres if all its projects materialised. On the other hadn, Shell has taken a big step in the proposed JV with Cosan. Valero, one of the largest refiners in the USA, has invested substantially in ethanol production units and disposing some of its petroleum refining facilities (Valero, 2010). In 2009, it is the third largest ethanol manufacturer in the USA and the world. The oil and gas giants have also heavily invested[5] in the R&D of various 2nd generation technologies in bio-alcohol fuels with JV and acquisition of many biotech firms.

[5] Accurate estimation is difficult because acquisition cost is normally not fully disclosed.

Drivers of evolution in ethanol industry structure

The bio-ethanol industry is not a new industry but rather one with a long history of serving the beverage and industrial markets. Nevertheless, fuel-ethanol industry is a rather new in many countries and firms, as rent seeking actors, will venture into this new, rapidly growing market and try to occupy and extract rents along the ethanol value chain. It should be also noted that predominantly downstream firms are integrating upstream and vice versa. The bi-directional movement contradicts the theory that firms should seek to occupy segments with higher value.

Downstream integration into the manufacturing segment by engineering firms, traditional food processors and commodity traders could be understood by taking a resource-based view. The strategic resources available to the firm could be utilised by the firm to gain long-term competitive advantage (Wernerfelt, 1984). The firm utilises its resources, e.g. technological knowhow or feedstock supply, to develop a new line of businesses in an expanding market.

The primary factor that motivates ethanol manufacturing firms to integrate upstream is security of supply for feedstock. Security of supply is in terms of quantity required as well as at a stable price. As shown in **Figure 2**, various feedstock for ethanol production have their existing markets which are far larger. Under most circumstances, ethanol manufacturer is a price taker.

However, there are socio-economy and political aspects of integration in upstream cultivation segments, which can incentivise or even prohibit integration. Land rights and ownership structure in a specific country are important factors that shape the governance structure of this segment. For example, there are land ownership restrictions based on whether the actor is an individual or corporation, local or foreign, when seeking control of a large piece of land for cultivation. But these restrictions are less stringent in Brazil compare with those in countries such as China, the Philippines and Indonesia. Corporations will have difficulties in integrating upstream to own land in these countries.

For the cultivation segment, the type of crop is an important factor. Some crops require substantial input such as seeds, fertiliser and pesticides. Other such as cassava requires only one off seeding purchase and the next planting material is obtained from previous harvesting. On the other hand, farm size, farm management, and farm labour also will have a significant impact on how and whether upstream integration may happen. For example, high number of small size family farms in cassava cultivation in central Thailand makes equity or even contract farming prohibitive when ethanol manufacturer attempts to integrate upstream. On the other hand, the traditional sugar-ethanol industry in Brazil owns a substantial portion of their sugarcane land or in long-term contracts with large farmers.

However, upstream integration into the feedstock production segment by oil and gas firms is not yet prevalent. Most oil and gas firms are not familiar with the traditional agriculture sector or agricultural commodity markets. BP and Shell chose to invest in the producing segment in Brazil rather than the USA, which might be attributable to sugarcane based ethanol delivering more environmental and carbon emission reduction benefits than their maize-based counterpart in the USA. Nevertheless, one of the crucial factors is the security of supply for sugarcane (site-specific due to bulkiness of cane) could be more easily enhanced.

Upstream integration of oil and gas firm into manufacturing segment will of course enhance security of supply of ethanol as the firm is required to fulfill regulatory targets. On the other hand, firms in the refining sector without upstream oil and gas exploration business are also moving out of this increasing lower margin business. This type of firm is venturing into a new substitute, ethanol, and seeking to obtain rents. A typical example is Valero. Other gasoline refiners and distributors, which have been moving upstream to source and market blended products include Suncor in the USA, and Greenergy in the UK.

On the other hand, the price of gasoline does have some bearing on the price of ethanol. Manufacturer's margin could be squeezed with high feedstock price and low ethanol price. In most

countries, with the notable exception of Brazil, these segments are dominated by the downstream oil and gas businesses. Ethanol volume is relatively small compared to gasoline in the overall blend. As petroleum refining capacity in excess in most parts of the world, refiners are generally reluctant to pursue ethanol blending and putting barriers to government mandate on blending, such as during the last decade in Japan. Ethanol manufacturers such as SEKAB in Sweden and Verasun in the USA, have integrated downstream, especially into the higher blend market segment, that might over the long-term provide a solution to the above situation. Before going into bankruptcy, Verasun Energy was the largest ethanol manufacturer with 11 operational plants and another 6 new plants in construction or under development. Verasun blended and marketed its own brand of E85 ethanol to 150 retailing stations across 15 states.

In our analysis, we observe that there have been a substantial numbers of entries from neighbouring industries indicating the ethanol industry boundaries are highly permeable. This permeability has created a structure where groups of firms with differing sectoral backgrounds and resources compete along the value chain. At this stage it is still difficult to determine which of the groups will emerge as the "winner", or it could be that different champions emerge from each of the groups?

Discussion and Conclusion

Coase (1937) argued that firms and markets are mutually substitutable governance mechanisms. Transactions will be organised within a firm that is vertically integrated when the cost of doing so is lower than the cost involved in using the markets. Developing from this concept, the transaction cost economists such as Klein *et al.* (1978) and Williamson (1979) suggests that due to the prohibitive cost of contracting, firm tends to integrate vertically especially there exist asset specificities. This propounds that the choice of governance structure is a decision based on the aim to achieve higher efficiency.

On the other hand, Bain (1956, 1959) proposed from an industrial organisation perspective that a firm only expands horizontally or vertically in order to respond to external market power or to

create and exploit market power. But, Joskow (2005) proposed that there was substantial support in the empirical literature for various efficiency motivations compared to a lesser support for market power exploitation as motivations in vertical integration.

Our analysis of the ethanol industry indicates that there are two important forces shaping the dynamic of ethanol industrial structure: security of supply and market access. It has to be acknowledged that the growing ethanol industry is a considerably tiny in both feedstock and fuel markets. Ethanol manufacturers have to compete for feedstock supply with a much larger and more mature food industry and ethanol manufacturers have to fight for market share as a substitute for gasoline in the downstream oil and gas segment dominated by "supermajor" integrated oil companies.

Another dynamic force that curves the evolution of the structure of the industry is the permeability of the industry boundaries. Due to ease of entry and the absence of major technological barriers, not only neighbouring industries with specific competitive advantages but also new start-ups can enter the manufacturing sector. However, the structure of the industry may change dramatically when 2nd generation technology becomes available.

As demonstrated above, there are social and political factors that prohibit or influence a firm's decision in vertically integrating. Firms in some countries do not integrate upstream to agriculture production and land ownership because there are neither substantial rents in the segment nor market arrangements which do not increase transaction costs. Any analysis of the governance structure has to take account of a wider perspective including environment and social-political factors in terms of regulation on land ownership, rural social structure, and farm size and practices.

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