Unlocking a path dependency? The case of Brazilian ethanol implementation in Petrobras
Oxford, UK Sept. 20th 2012

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Oil firms and Biofuels ¿Transition from a path dependency system?

• Lock-in System based on oil products
  • Fuel-Infrastructure-Subsidies-Car/Engines-Routines-Distribution-Petrol Stations-Safety/Norms-Oil income (certain countries)
  • System Technological trajectory (incremental changes)
  • Changes – Brazilian case Hydrous Alcohol and Anydrous as additive (up to 25%) - Subsidies-Car/Engines-Routine-Consumer experience

• Lock-in System based on oil products plus biofuels:
  • Changes:
    • Flexfuel (Paradigm change)
    • Climate change agenda Renewables Push
    • Production costs reduction/increase in scale
    • New technologies/New business opportunities
    • ¿Shift in technological trajectory based on first and second generation biofuels?
Petroleum Companies and Biofuels (Evolution)

• Main factors 1970´s
• High oil prices
• Need to develop ethanol run car engines
• Energy Security
• Policies:
• High subsidies for production and implementation
• Design specifically for development of biofuels

• Main factors 2012: New conditions
• High oil prices
• Car paradigm change in market. Hybrid cars/Flexfuel
• Climate change/CO2 emissions
• New technologies
• Policies:
• Blending mandates operating in several countries EU/Brazil/US
Peaks in Oil price; characteristic factor for Biofuels

Source: International Energy Agency 2012
Main Focus of the Research

The study uses the approach of path dependency and argues that Oil firms have become locked in an oil dependent path that has recently been challenged by the increasing use of biofuels.

One of the questions that the study tries to answer is whether there is a trajectory shift due to ethanol implementation of oil firms and the drivers behind the decision to implement biofuels.
Motor fuel production system

SOCIO TECHNICAL REGIME

Driving forces:

*Internal vs External Forces* (Oil Prices, Energy Policy, Agroindustry, etc.)
Motor Fuel Production System (MFPS)

Type of Fuel in the market (gasoline vs ethanol)

INFLUENCING ELEMENTS
INTERNAL (FIRM)
EXTERNAL (Gov/AutoInd/Sugarcane Prod)

Dominant
Locked-in Fuel

NAT TRAJECTORY
INCUMBENT/DOMINANT
FIRM

TECH SHIFT
(DEVIATES)

CONFLICT/DESTABLISHMENT

Alternative
Fuel (strategic
niche)

NICHE

MARKET NICHE

DOMINANT
THEORETICAL LITERATURE Path Dependence, Lock in and Lock out

- Zunsheng (1994) technological change is not a linear process. Arthur (1989), David (1985) and Roehrl and Riahi (2000) Initial conditions are crucial in technological choice that determines the technological path to be followed.

- Arthur (1989) when two technologies compete for adoption ‘insignificant events’ may give one of them a leading advantage and become dominant. Increasing returns favours the chances of adoption, once a course has been set difficult to change, that could have inferior long-run potential with respect to others.

- Hughes (1989) within LTS, radical changes difficult to occur.

- Geels (2004,2010,2011), Radical innovation come from niches and may produce a REGIME to shift and INCUMBENT firms into reorientation.
LARGE TECHNICAL SYSTEMS (LTS)
- Interdependence of technologies, sunk costs, components, and practices.

MOTOR FUEL PRODUCTION SYSTEM
- LTS with increasing returns, economies of scale and path dependent.
  Many decades of incremental innovations.

- LOCKIN OIL PATH DEPENDENCY
  Over a century, without major disruptions.

However,
NEW CONDITIONS FOR OIL FIRMS
- Stringent environmental quality specifications for their products (Szklo and Schaeffer 2007) Biofuel mandates, following regulations for CO2 reductions and other pollutants.
  Modifying operations at various levels of the firms
METHODS

- Case study analysis.

- Qualitative Interviews.
  Company/Government/Industry Experts for each case.

- Additional data (Patents/Investments for first and second gen.

- R&D data
PETROBRAS

• A Brazilian Oil Company/Leader in Brazil.
• Operates in 13 countries
• 2011 Revenue – 145,915 billion dollars
• Partly state/party private owned
• 81,918 Employees

ETHANOL IN BRAZIL
• SECOND PRODUCER IN THE WORLD
• SUGARCANE BASED/LOWEST PRICE
• PIONEER IN LARGE SCALE IMPLEMENTATION
• HUGE AVAILABILITY OF ARABLE LAND FOR ETHANOL (ONLY 1-2% OF ARABLE LAND USED FOR ETHANOL PRODUCTION)
**MOTOR FUEL PRODUCTION SYSTEM HISTORY**

1973 - - First “oil shock”
1975 - - PROALCOOL (ethanol program)

BRAZIL AN OIL IMPORTER
BALANCE OF PAYMENTS
PROBLEMS/SUGAR CANE
PRICE VERY LOW

1979 - - Second “oil shock”
1979 - - First Alcohol Powered Car T
1982 - - Gasohol 78% Gasoline + 22% Ethanol
1985 - - 96% of TOTAL CAR SALES WERE OF ALCOHOL ONLY CARS 4.5MILLION CARS
1989 - - Alcohol Supply Crisis
1997 - - Alcohol Production Excess
1998 - - Ethanol Addition Increase (24%)
2000 - - Ethanol Addition Diminution (20%)
2001 - - Ethanol Addition From 20 to 26%
2003 - - Flex Fuel Car (2.6% of New car sales)
2005 - - Ethanol Addition 25%

- Biodiesel addition to diesel (2% allowed in 2005, 5% obligatory by 2013)
2009 - - Flex fuel Car (NEARLY 90% OF NEW CAR SALES)

END OF PROALCOOL IN 1990.
ECONOMIC INCENTIVES
ETH 59% COST OF GASOLINE
PETROBRAS CHANGE OF STRATEGY
Petrobrás (PB) Ethanol Implementation

**PATH DEPENDENCY**

System

**INFLUENCING ELEMENTS**

INTERNAL (FIRM)

EXTERNAL (Gov/AutoInd/Sugarcane Prod)

**Unlocked? First Generation**

**1931 1954**

ANHYDROUS 5%


HYDROUS 20-25% A/HYDRATED/2ND GEN
Domestic sales of ethanol and automotive gasoline 2001-2010

Source: ANP 2011 Report. Ethanol includes both hydrous and anyhdrous. Gasoline does not include anhydrous, only Gasoline A.

2007-2008 PETROBRAS CHANGES STRATEGY, EMBRACES ETHANOL AND CREATES A NEW SUBSIDIARY: PETROBRAS BIOCOMBUSTIVEL
Sugarcane production requires about 5% of Brazil’s land devoted to primary food crops. If sugar prod is taken into account it becomes 7.5%.
PETROBRAS STRATEGY

- Associated with Ethanol Producers from 2008!
- 1st Generation ethanol (Brasil)
- 2nd Generation biofuels (CENPES)
- From 2008 PB Biofuel Business Unit (Petrobras Biocombustiveis)
- Challenged by large ethanol market share (prox 50%)
- Based on 8 decades of ethanol blending and distributing in Brazil.
- Export infrastructure planned (ethanol specific pipelines)
- Planned in 2011-2014, 4.1 $ US Billion for Biofuels (300Mill R&D)
- Announced that PB Business saved 1 million tons of CO2 (Sust. Report 2010).
Sao Paulo and Central West account for 80% of Ethanol prd.
PETROBRAS Ethanol Export Strategy

New Ethanol Pipeline (800 km)

New Water Way for Ethanol

Ethanol Export Capacity
8.0 Millions m³ in 2012

Marine Terminal
Rio de Janeiro

Marine Terminal
São Paulo

Source: Petrobras
Petrobras Ethanol Production Capacity and Market Share

<table>
<thead>
<tr>
<th>Ethanol Production</th>
<th>Number of Plants</th>
<th>Production capacity (Million liters)</th>
<th>Market share in Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2006</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2012</td>
<td>9</td>
<td>893</td>
<td>4%</td>
</tr>
<tr>
<td>2015</td>
<td>9</td>
<td>5600</td>
<td>12%</td>
</tr>
</tbody>
</table>

Extension capacity Planned
Increase of 627% from 2011

Source: Own elaboration with data from Petrobras Business Plan 2011-2015 and Petrobras Magazine
# Petrobras Biofuel R&D

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biofuels R&amp;D</td>
<td>32</td>
<td>300</td>
</tr>
<tr>
<td>Average per year</td>
<td>8</td>
<td>75</td>
</tr>
<tr>
<td>Share of total R&amp;D</td>
<td>5%</td>
<td>7%</td>
</tr>
</tbody>
</table>

Source: Own elaboration with data from Petrobras Business Plans
Petrobras Investments in Biofuels

2011-2015 INVESTMENTS
US$ 4.1 billion

- Ethanol: 47%
- Ethanol Logistics: 7%
- Biodiesel: 14%
- R&D: 1.3%
- Other: 0.6%

77% on Ethanol

Market share Pbio+Partners:
- 2011: 5.3%
- 2015: 12%

Ethanol supply (million m³)
- 2011: 1.5
- 2015: 5.6

Biodiesel supply (‘000 m³)
- 2011: 735
- 2015: 855

Source: Petrobras 2011-2015 Business Plan
Biofuel Patents

- Bio-diesel: 4854 (45%)
- Cellulosic Bio-ethanol: 6023 (55%)

Source: Espacenet
## Ethanol patents

<table>
<thead>
<tr>
<th>Firms doing R&amp;D</th>
<th>Patents</th>
<th>% of Total Patents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input etanol</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biotech (Novozymes, Genencor, etc)</td>
<td>400</td>
<td>89.8%</td>
</tr>
<tr>
<td><strong>Ethanol Producers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productoras, ej. Abengoa, ADM, Cargill</td>
<td>9</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Oil firms/Distributors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroleras, ej. Chevron, Texaco, Shell</td>
<td>36</td>
<td>8%</td>
</tr>
</tbody>
</table>

Source: Karmarkar-Deshmukh and Pray (2008) data from USPTO
Patents in Biofuels

Biofuel Patents


- Bio-diesel
- Cellulosic Bio-ethanol

Patents by Oil Firms


- BP
- Shell
- Petrobras

30 years vs 12 years

Fuente: Own elaboration with data from Espacenet
Biofuel Patents in last six years by type

Source: Own elaboration with data from Espacenet
Patents in Alternative Fuels (non fossil) by Oil Firms

Source: Own elaboration with data from Espacenet (Historic)
Oil Firm Patents by type of fuel

Aprox. 80% de las Patentes son en el periodo 2006-2012

Fuente: Espacenet. Clasificación para tecnologías de combustibles no fósiles. Hasta 12/08/2012
## Results

<table>
<thead>
<tr>
<th>PETROBRAS</th>
<th>First Generation</th>
<th>Second Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To what extent, rate and</td>
<td>Expansion in Downstream and Midstream. World leaders,</td>
<td>Demonstration stage/Behind peers</td>
</tr>
<tr>
<td>direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological Shift/Trajectory</td>
<td>“End of pipe” implementation</td>
<td>Two patents related to Renewable /one to Biofuels.</td>
</tr>
<tr>
<td>Technical Interrelatedness</td>
<td>Adjustments implemented until (Blend wall) for Anhydrous.</td>
<td>Similar</td>
</tr>
<tr>
<td>Economies of Scale</td>
<td>Started production in 2010</td>
<td>Potentially.</td>
</tr>
<tr>
<td>Irreversibility</td>
<td>Implementation seen as irreversible.</td>
<td>No</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>PETROBRAS</th>
<th>First Generation</th>
<th>Second Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Major Changes throughout, Became the Largest Distributor of Ethanol and large exporter.</td>
<td></td>
</tr>
</tbody>
</table>

- More substantial changes happen when oil firms enter the upstream business of biofuels.
- Downstream oil firms, technical adjustments, which although costly in the beginning it has not represented a substantial technological or logistical problem for a large oil firm.
Conclusions

• TRANSITION IN PROCESS
• SUSTAINED BIOFUEL MANDATE SINCE 1931
• CHANGE OF FIRM STRATEGY FROM 2008.
• LOCKED IN FIRST GENERATION ETHANOL.
• LARGE INVESTMENT IN 1ST AND 2ND GEN.
• INCREASING SHARE IN BIOFUEL PRODUCTION AND TECHNOLOGICAL DEVELOPMENT (ALLIANCES AND OWN R&D)

• POSSIBLE SHIFT IN TECHNOLOGICAL TRAJECTORY (R&D AND PATENTS)
• EXPANSION IN AREAS OF KNOWLEDGE AND CAPABILITIES (AGRIBUSINESS/BIOTECH)
• NEW MARKET OPPORTUNITIES
Thank you!

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