SUPPLY RISKS OF BIOFUELS

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Agenda

- Biofuels scalability metric – why important?
- How risky is the supply of biofuels?
- Risk mitigation strategies
- Closer look at diversification strategies
Motivation: Biofuels Scalability

- **Scalability metrics:** to evaluate the performance of a system or technology as a function of scale

- **Existing metrics:**
  - Cost competitiveness
  - Environmental impacts
  - Resource constraints (food/fuel competition)

- **Our proposed (fourth) metric:** risk of supply (energy security concerns)
Example: Brazil 2010/2011

- Lowered blending mandate: from 25% to 20%
- Reduced import tariff: by 20%
- Imported biofuels from US: 1.1 billion liters
- Doubled sugar prices in international markets (15 to 30, cents per pound)
- Lower growth rate of sugarcane yield
- Lower investment in refining capacity
How Risky is the Supply of Biofuels?
Country-Crop Yield Residuals
(around trend line)

Brazil Sugarcane

China Soybeans

US Corn

EU Rapeseed
Aggregate Fuels Market Risks

- **Status quo: volatile fuel market**
  - Despite a less risky supply of crude oil (Killian, 2009)

- **Welfare analysis:**
  - Oil prices high in good times and low in bad times
  - Higher social costs of biofuels shocks compared to (demand-driven) fossil fuel shocks
Expected Future: Higher Volatility of Fuel Market

- **Price equation:** \( P = Xq^{-\gamma} \), \( \gamma \in [5,12] \)

- **Expected future volatility range**
  - Share of biofuels = 25% of total fuels
  - Baseline (crop) risk = 30%
    - Smoothed by storage, trade
  - Biofuels shocks absorbed by the oil sector
  - (Upper-bound) final supply side risk = 5%

- **Rough estimate:** a range of [25%-60%] annual price volatility (read with caution)

\( P \): price
\( q \): supply
\( \gamma \): elasticity parameter
Dynamics of Biofuels Feedstock Risks

- **Long-term trend of yield risks:**
  - Climate change
  - Crop engineering

- **Production scale:**
  - Larger and more connected network
  - Lower capacity of alternative supply channels

- **Technology generation**
  - First generation: Food/fuel competition
  - Second generation: Food/fuel complementarity
Closer Look at Diversification Strategies
Diversification: Distance and Yield Correlations

The diagram shows a scatter plot with points representing the yield correlation against distance. The x-axis represents distance in miles, ranging from 0 to 2000 miles. The y-axis represents yield correlation, ranging from -0.4 to 1.0. The data points are scattered, and there is a trend line indicating a negative correlation between distance and yield correlation.
Diversification and Corn Portfolio Risks

![Graph showing Expected Yield (Bushels / Acre) and Ratio of Yield / S.D. against Number of States.](image)
Optimal Crop/State Portfolio

- **Seven major energy crops:** corn, sugar beet, sugarcane, wheat, soybeans, sunflower, sorghum

- **Limited production capacity per state**
  - Optimal portfolio as a function of demand scale

- Land price not included
# Profile of Major Energy Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total Energy Capacity (PJ/Y)</th>
<th>Energy Yield Intensity (GJ/Ha)</th>
<th>S.D of Yields</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>2772</td>
<td>31.9</td>
<td>13.9</td>
</tr>
<tr>
<td>Soybeans</td>
<td>603.75</td>
<td>6.8</td>
<td>4.6</td>
</tr>
<tr>
<td>Wheat</td>
<td>441</td>
<td>10.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Sorghum</td>
<td>73.5</td>
<td>13.5</td>
<td>10.7</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>63</td>
<td>88.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>63</td>
<td>55.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Sunflowers</td>
<td>21</td>
<td>10.0</td>
<td>209</td>
</tr>
</tbody>
</table>

* Current US transportation final energy consumption = 28400 PJ
* PJ = 1 e6 GJ
Optimization Model

Max $\sum_{q_{s,c}}^{T} E_t(U(c_t)) = \sum_{t=1}^{T} E_t \left( \frac{c^{1-\gamma}}{1 - y} \right)$

s.t.

$E \sum_{crops} \sum_{states} q_{s,c} = \text{Total energy needs}$

$q_{s,c} < \text{Local production capacity}$

$\gamma$: risk-aversion parameter
$c$: total consumption of fuel
$q_{s,c}$: supply of type (c) from state (s)
$T$: time horizon of existing data
Optimal Crop Portfolios

- Corn
- Sugarcane
- Sugar beet
- Soybeans
- Sorghum
- Wheat
- Sunflower

Yield

Riskiness

Energy Yield (GJ/Ha)

Standard Deviation

Measure of Risk Aversion
Optimal Crop Portfolios

- Corn
- Sugarcane
- Sugar beet
- Soybeans
- Sorghum
- Wheat
- Sunflower

![Graphs showing total share of crops and energy yield for different measures of risk aversion for 1000PJ/Year and 2000PJ/Year.](image)
Conclusion
Summary: Biofuels and Energy Security

- Risky supply of biofuels feedstock
  - Feedstock supply shocks: Orthogonal to the state of the economy
  - Competing demand shocks: Correlated with the state of the economy
- Quantitative measures of feedstock supply risks
- Risk mitigation strategies
  - Diversification strategy: effective but costly
- Next steps:
  - Further results on optimal diversification
  - Storage
- We Appreciate Financial Support by BP
Risk-Mitigation Solutions

Storage

• Cost of storage
• Decay
  • Feedstock
  • Fuel
• Limits to smoothing by storage

Diversification
Real Price of Crude Oil (1960-2011)
From Yield Shocks to Feedstock Price: Annual Corn Prices

- Yields
  - Storage
  - Demand shocks
  - International trade shocks

![Graph showing annual corn prices from 1970 to 2010](chart.png)
Energy Conversation Calculations

- **Energy content**
  - Barrel of crude oil =
  - Litter of ethanol =

- **Total US transportation fuels**
  - Oil equivalent per day
  - Total energy per year (GJ / Y)
Real World Example: Brazil 2010/2011

- High sugar prices in international markets
- Lower growth rate of sugarcane yield
- Lower investment in refining capacity

19% lower production (5.1 b lit / year)
Optimal Crop Portfolios
(using mean-variance framework)

Measure of Risk Aversion

Total Share of Crops

100MGJ / Year

1000MGJ / Year

500MGJ / Year

4000MGJ / Year

- Corn
- Sorghum
- Soybean
- Sugar Beet
- Sugarcane
- Sunflower
- Wheat