A conceptual framework for the analysis of biofuel supply chains in an imperfect world

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Jorge Andrés Moncada Escudero
Outline.

- Introduction
- Research question
- Conceptual framework
- Case study
- Agent-based model development
- Results and discussion
- Conclusions
Introduction

• The depletion of fossil fuels, growing concerns about energy security and global climate change have led to growing worldwide interests in biofuels.

One of the fundamental barriers to the emergence of biofuel supply chains is related to economics.
Introduction. Cont’d

• Some stylized facts on the global emergence of biofuels
  - High crude oil prices.
  - Favourable institutional framework
    • Formal institutions (Policies)

Mainstream conceptual frameworks include neoclassical economics.

“Decision makers can satisfice either by finding optimum solutions for a simplified world, or by finding satisfactory solutions for a more realistic world”

Herbert Simon
Research question

- What conceptual framework enables a systematic analysis of the emergence of biofuels supply chains that accounts for the interaction between technical and social (actors and institutions) components?
Conceptual framework

What is an institution?

“Institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction. In consequence they structure incentives in human exchange, whether political, social, or economic”

Conceptual framework

• Frameworks:
  • Four layer model: Framework for institutional analysis
  • MAIA framework: Modelling Agent systems using Institutional Analysis

• Theories:
  • Complex adaptive systems theory
  • Socio-technical systems theory
  • (Neo)institutional economics theory

• Models
  • Agent-based models ("If you did not grow it, you did not explain its emergence")
## Conceptual framework

- **Modelling approaches:**

<table>
<thead>
<tr>
<th>Agent based model</th>
<th>Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>No limited by mathematical tractability</td>
<td>Limited by mathematical tractability</td>
</tr>
<tr>
<td>Represent a system's individual components and their behaviors</td>
<td>Describe a system with variables representing the state of the whole system</td>
</tr>
<tr>
<td>Multi-level problems</td>
<td>One-level problems</td>
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<tr>
<td>Bottom-up approach (Emergence)</td>
<td>Top-down approach</td>
</tr>
<tr>
<td>Computation intensive</td>
<td>Computation intensive</td>
</tr>
<tr>
<td>&quot;soft&quot; nature of variables</td>
<td>&quot;hard&quot; nature of variables</td>
</tr>
<tr>
<td>Very difficult to produce useful software</td>
<td>Difficult to produce useful software</td>
</tr>
</tbody>
</table>
Conceptual framework

Physical system (infrastructure)

Aggregate behaviour of the system
(production and consumption of biofuels, market structure)

Network of Actors
(farmers, investors, producers, distributors)

Institutions
(norms, policies, regulations)
Conceptual framework.
Case study: Bioethanol production in Brazil

• In 1975, the “ProAlcool” program started.
  • Compulsory blending of anhydrous ethanol in regular gasoline.
  • The government actively pushed the automobile industry to develop automobiles which could run on a 100% blend of ethanol fuel (neat vehicles).

• In 1990 the sale of neat vehicles collapsed due to high sugar prices and supply shortages of ethanol.

• In 2003 the flex fuel vehicles were introduced in the market.
Agent-based model development

“model the problem not the system”

Modelling question

- What measures are necessary to establish a bio-ethanol based aviation kerosene supply chain within the existing bio-ethanol market in Brazil and what projected impacts might these have on the bio-ethanol market behavior?
Agent-based model development.

Cont’d

System decomposition

Physical system

Network of actors

Institutions
Agent-based model development.

Cont’d

Model conceptualization

Emergent key outcomes of interest

- Biojet demand satisfaction
- Δ biojet price & kerosene price [R$/L]
- Biosuccinic acid demand satisfaction
- Biosuccinic acid price

Levels of institutional analysis:

INSTITUTIONAL ENVIRONMENT: Market regulation

GOVERNANCE: Governance structures and transaction costs

RESOURCES ALLOCATION AND EMPLOYMENT: Strategic decisions

Policies - exogenous:
- Such as:
  - Trade policies
  - Blending mandate
  - Price controls

External variables - exogenous:
- Such as:
  - Weather
  - World oil price
  - World sugar price

Network level:

Farmer
- Supply contract

Distributor

Farmer
- Processing plant

Car driver

Agent level:

Agricultural land
- Sugarcane

Expected profits
- Efficiency

Production ratios
- Biojet production
- Biosuccinic production

Processing plant

System output

System input

Endogenous
Agent-based model development.

Cont’d

Pricing mechanism
Agent-based model development. Cont’d

Model narrative
Agent-based model development. Cont’d

Assumptions

• The aviation sector is assumed to be willing to and able to pay the premium which is required for biokerosene over regular kerosene.

“All models are wrong but some are useful”

George Box

\[ D_{\text{biokerosene}} \neq f(P_{\text{biokerosene}}) \]

\[ D_{\text{biokerosene}} \geq \text{Prod}_{\text{biokerosene}} \]

\[ P_{\text{kerosene}}, P_{\text{gasoline}} = f(P_{\text{crudeoil}}) \]
Agent-based model development. Cont’d

Snapshot
Results and discussion
Results and discussion
Conclusions

• The proposed conceptual framework offered an alternative analytical tool to study biofuel supply chains. The framework recognizes that a biofuel supply chain is more than a technological construction or organizational construction.

• The conceptual framework enabled the incorporation of social structures into an agent-based model right from the conceptualization phase.
Conclusions

- Some element (consumer, government) in the system will have to finance the price difference between kerosene and biokerosene.

- A level playing field for fuel is required either through a change in the competing road transport fuel market or through a change in the aviation market.
Future work

• Investigate the influence and feasibility of different policy interventions supporting adoption of energy crops and investment in biofuels production capacity in the UK in the period 2015 - 2050.
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Questions