The end of the Kyoto Protocol era: What can we learn from the global trade of Emissions Reduction Units applying network analysis?

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June 10, 2021
Designing Effective Regulation for Carbon Markets at the International, National, and Subnational Levels

How can we design effective regulation for carbon markets worldwide?

Overview

1. Introduction and motivation
2. Background
3. Methodology
4. Data
5. Results
**Market mechanisms under the Kyoto Protocol**

- **Assigned Amount**: Base year GHG emissions \( \times (1 - \text{emission reduction target} \%) \times 5 \text{ years} \)
- **Emissions** = anthropogenic greenhouse gases (CO2, CH4, N2O, Industrial gases) from all sectors on the territory of a country (excluding aviation and international ship)
Market mechanisms under the Kyoto Protocol

- Joint Implementation (JI)
  - Emissions Reduction Units (ERUs)
  - Between industrialized countries

- Clean Development Mechanism (CDM)
  - Certified Emissions Reduction (CERs)
  - Between industrialized and developing countries

- Emissions trading
  - Assigned Amount Units (AAUs)
  - Between industrialized countries
The international carbon market under Kyoto

- At best Kyoto units are zero-sum game for the atmosphere
- Initial idea: Countries with Kyoto commitments invest in cheaper projects in other countries to generate offsets for compliance

However, the market developed differently:

- Many countries or companies within the host countries did invest without the direct involvement of foreign entities into reductions projects and sold certificates on the global market
- National and regional ETS allowed companies to use ERUs for compliance leading to
  - indirect linking of different ETS (Haites 2016)
  - new market participants (companies) with different interests and preferences than countries entered the global market
Motivation: Focus on Joint Implementation (ERUs)

- Lack of understanding on the functioning of the global market for ERUs
- Entire market from beginning to end can be analysed: JI market is closed, generation of ERUs is over
- Design of JI market closest to potential new carbon market under the Paris Agreement
  - All Parties have reduction targets
  - Different level of ambition in NDCs bears risk for new "hot air" (Schneider and La Hoz Theuer, 2019)
Issues

- Incentive for countries with AAU surplus to sell ERUs from non-additional or over-credited projects (Kollmuss et al. 2015)
- Governments hold and use ERUs for their compliance even though they do not actively trade as ERUs surrendered by companies in national ETS end up on government accounts
- Quality of certificates and environmental integrity issues related to the origin of certificates will not be considered in governmental compliance decision
Background

Issuance of ERUs

Share of issued ERUs by host country

Source: IGES (2020)
Questionable additonality of JI Projects

<table>
<thead>
<tr>
<th>Project types</th>
<th>Registered projects</th>
<th>% of ERUs</th>
<th>Additionality</th>
<th>Over-crediting</th>
<th>Inventory inconsistencies</th>
<th>Overall environmental integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous ignition of coal waste piles</td>
<td>78</td>
<td>26.1%</td>
<td>Not plausible</td>
<td>Likely to be very significant</td>
<td>Significant</td>
<td>Low</td>
</tr>
<tr>
<td>Energy efficiency in industry and power production and distribution</td>
<td>164</td>
<td>23.1%</td>
<td>Questionable</td>
<td>Not known</td>
<td>None found</td>
<td>Questionable</td>
</tr>
<tr>
<td>Associated petroleum gas utilization</td>
<td>22</td>
<td>13.9%</td>
<td>Not plausible</td>
<td>Likely to be very significant</td>
<td>Significant</td>
<td>Low</td>
</tr>
<tr>
<td>Natural gas transportation and distribution</td>
<td>32</td>
<td>9.8%</td>
<td>Not plausible</td>
<td>Some over-crediting likely</td>
<td>None found</td>
<td>Low</td>
</tr>
<tr>
<td>HFC-23 abatement from HCFC-22 and SF₆ abatement</td>
<td>4</td>
<td>6.4%</td>
<td>Plausible</td>
<td>Likely to be very significant</td>
<td>Significant</td>
<td>Questionable</td>
</tr>
<tr>
<td>N₂O abatement from nitric acid</td>
<td>41</td>
<td>4.5%</td>
<td>Plausible</td>
<td>Unlikely</td>
<td>Largely consistent</td>
<td>High</td>
</tr>
</tbody>
</table>

Source: Kollmuss et al. (2015)
Studies on JI market (Elsworth and Worthington, 2010; Kollmuss et al., 2015; Shishlov, Morel, et al., 2016) have not assessed entire Kyoto period or linked information from different registries.

Network analysis increasingly applied to financial markets. Few studies on EU ETS: Karpf et al. (2018), Liu et al. (2018) and Borghesi and Flori (2018) and non with focus on JI including data outside EU ETS.
Research question

- What is the effect of international certificates on trading network in regional ETS?
- Which sectors and countries play a central role in the trading network?

Hypotheses:
- Ukraine, Russia and other Eastern European countries with "hot air" play major role as sellers
- ERUs are used for compliance: there are only few transactions between host country accounts and investing/buying entities
- Sectors which are either familiar with the project types (e.g. energy industry) or experts in trading (e.g. banks, brokers, wholesale commodity traders) will play a important role as intermediaries
Network framework

- Network graph $G = (\mathcal{V}, \mathcal{E})$
- Nodes $\mathcal{V} = \{1, ..., N\}$
- Directed links between nodes $\mathcal{E} \subseteq \mathcal{V} \times \mathcal{V}$
- Network graph represented by its adjacency matrix $D = [D_{ij}]$, where $D_{ij}$ takes on the value 1 if one edge points from seller $i$ to buyer $j$
- Links/edges weighted by trading volume
Methodology

Centrality measures

Quantifying the role of agents in the network:

- **Degree centrality**: The sum of in and outgoing trades of one node
- **Out-degree centrality**: Identify important supplier of ERUs
- **Betweenness centrality**: Measures for each node the number of shortest path that pass through the node (Brandes, 2001). Indicator for key brokers and intermediaries
- **Eigenvector centrality**: Measure of influence on the trading network. Takes into account the connection of nodes to other important nodes
- **Authority centrality**: Measure for an important trader who is strongly linked with many important trading hubs
The effect of economic activity and location of trader on the role of in the market

- OLS regression analysis to investigate whether characteristics of market participant are a good predictor of traders’ importance in the trading network of ERUs
- separate regressions for each centrality measure and both commitment periods
Registry data

EU ETS
- Transfer data 2005-2018
- About 42,000 registry accounts
- 72,327 ERU transfers

Swiss ETS
- Data on 55,580 transfer between 2007-2018
- About 1,000 registry accounts
- 5,580 ERU transfers
Firm level information

- Matching with ORBIS database to retrieve NACE Rev. 2 codes on a 4-digit level
- Swiss registry data delivery comes with NOGA 2008 codes on 4 digit level that corresponds to NACE codes
Project level data

- Each registered JI project receives an unique ID in the International Transaction Log (ITL), as well as a UNFCCC reference number
- Information on project track
- Information on project title, project type, host country available from UNEP and UNFCCC
Results

Project network
## JI network

**Table: Network descriptives**

<table>
<thead>
<tr>
<th></th>
<th>CP1 and CP2</th>
<th>CP1</th>
<th>CP2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nr nodes</td>
<td>8,450</td>
<td>3,481</td>
<td>6,658</td>
</tr>
<tr>
<td>Nr edges</td>
<td>20,972</td>
<td>14,700</td>
<td>6,924</td>
</tr>
<tr>
<td>Nr transactions</td>
<td>51,732</td>
<td>21,430</td>
<td>30,302</td>
</tr>
</tbody>
</table>
JI network
Results: Regions and countries

A: Weighted in-degree centrality
B: Out-degree centrality
C: Unweighted degree centrality
D: Betweenness centrality
E: Eigenvector centrality
F: Authority score

Reference: Region 1 (GR, IT, PT, ES, CY, MT)
Results: Sectors

A: Weighted in-degree centrality
B: Out-degree centrality
C: Unweighted degree centrality
D: Betweenness centrality
E: Eigenvector centrality
F: Authority score

Conclusion

- ERUs were mainly generated by countries with excess AAUs such as the Ukraine and Russia, which may hint at the “laundering” of “hot air”

- Companies trade through jurisdiction with the minimum legal or regulatory requirements: Long trading chains that involve countries such as Jersey or Switzerland outside of the main issuance countries (e.g. Ukraine and Russia) and surrendering countries (e.g. Germany, New Zealand)

- Financial sector, the information and communication, and the wholesale sector play an important role. CH: energy and commodity traders

- ”hot air” finds its way into the system and can have a negative impact on environmental integrity

- When including offsets, quantitative limits in each of the linked markets are important as this helps to ensure supplementary
Thank you for your attention!

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