The Law and Economics of CO$_2$ as a Pollutant and Commodity

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We think of $\text{CO}_2$ as the greenhouse gas (GHG) causing global warming.

The Stern Report and the several IPCC (Intergovernmental Panel on Climate Change) reports are gaining acceptance.
In its most recent report (AR4 Synthesis Report November 17, 2007) the IPCC has written:

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.
The report goes further to say:

Most of the observed increase in globally-averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations.
Table 3.1  Highlights of possible climate impacts discussed in this chapter

<table>
<thead>
<tr>
<th>Temp rise (°C)</th>
<th>Water</th>
<th>Food</th>
<th>Health</th>
<th>Land</th>
<th>Environment</th>
<th>Abrupt and Large-Scale Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1°C</td>
<td>Small glaciers in the Andes disappear completely, threatening water supplies for 50 million people</td>
<td>Modest increases in cereal yields in temperate regions</td>
<td>At least 300,000 people each year die from climate-related diseases (predominantly diarrhoea, malaria, and malnutrition)</td>
<td>Permafrost thawing damages buildings and roads in parts of Canada and Russia</td>
<td>At least 10% of land species facing extinction (according to one estimate)</td>
<td>Atlantic Thermohaline Circulation starts to weaken</td>
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<td>Reduction in winter mortality in higher latitudes (Northern Europe, USA)</td>
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<td>80% bleaching of coral reefs, including Great Barrier Reef</td>
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<td>2°C</td>
<td>Potentially 20 - 30% decrease in water availability in some vulnerable regions, e.g. Southern Africa and Mediterranean</td>
<td>Sharp declines in crop yield in tropical regions (5 - 10% in Africa)</td>
<td>40 – 60 million more people exposed to malaria in Africa</td>
<td>Up to 10 million more people affected by coastal flooding each year</td>
<td>15 – 40% of species facing extinction (according to one estimate)</td>
<td>Potential for Greenland ice sheet to begin melting irreversibly, accelerating sea level rise and committing world to an eventual 7 m sea level rise</td>
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<td>High risk of extinction of Arctic species, including polar bear and caribou</td>
<td>Rising risk of abrupt changes to atmospheric circulations, e.g. the monsoon</td>
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<td>3°C</td>
<td>In Southern Europe, serious droughts occur once every 10 years</td>
<td>150 - 550 additional millions at risk of hunger (if carbon fertilisation weak)</td>
<td>1 – 3 million more people die from malnutrition (if carbon fertilisation weak)</td>
<td>1 – 170 million more people affected by coastal flooding each year</td>
<td>20 – 50% of species facing extinction (according to one estimate), including 25 – 60% mammals, 30 – 40% birds and 15 – 70% butterflies in South Africa</td>
<td>Rising risk of collapse of West Antarctic Ice Sheet</td>
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<td>1 - 4 billion more people suffer water shortages, while 1 – 5 billion gain water, which may increase flood risk</td>
<td>Agricultural yields in higher latitudes likely to peak</td>
<td></td>
<td></td>
<td>Collapse of Amazon rainforest (according to some models)</td>
<td>Rising risk of collapse of Atlantic Thermohaline Circulation</td>
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</tbody>
</table>
The Supreme Court on April 2, 2007 in a 5 to 4 decision decided that CO$_2$ was a pollutant and the EPA could regulate auto emissions of the GHG (Chemical & Engineering News, April 3, 2007).
The Lieberman-Warner Bill, reported to the Senate Floor on December 5, 2007 calls for:

- A national cap and trade program for CO$_2$ emissions.
- Tax credits for CO$_2$ sequestration at $20/ton for CCS (Carbon Capture Storage) and $10/ton for EOR (Enhanced Oil Recovery).
CCS is considered a primary form of carbon emission abatement. It involves:

- Enhanced Oil Recovery (EOR) methods through which CO$_2$ remains in the oil reservoir.
- Enhanced coal bed methane recovery (ECBM) through which the CO$_2$ adheres to the coal.
- Injection of CO$_2$ into depleted oil and gas reservoirs.
- Injection of CO$_2$ into deep saline aquifer reservoirs.
The first two types of CCS, treat CO$_2$ as a commodity.

In the second two types of sequestration, CO$_2$ is considered a waste or pollutant.

<table>
<thead>
<tr>
<th>Sequestration Option</th>
<th>North American Capacity</th>
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<tbody>
<tr>
<td>Deep Saline Formations</td>
<td>3,700 gigatons</td>
</tr>
<tr>
<td>Coal Seams (ECBM)</td>
<td>65</td>
</tr>
<tr>
<td>Depleted Gas Reservoirs</td>
<td>40</td>
</tr>
<tr>
<td>Depleted Oil Reservoirs (including EOR)</td>
<td>12</td>
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</table>
CO₂ has a 30 year history as a commodity in enhanced oil recovery.

The design of markets for CO₂ as a commodity in EOR will guide the way markets develop for CO₂ as a pollutant.
Potential Anthropogenic Sources of CO$_2$

- Potential Source
- CO$_2$ Contract Executed

Denbury Resources Inc.
Oddly there are substantial legal impediments for CCS when CO$_2$ is classified as a pollutant. Liability issues escalate when underground storage becomes a “dump site”.

CCS is slowed by a “lack of technical standards” and “liability issues”.
With respect to liability issues:

- There are questions involving induced seismic events, subsurface trespass, groundwater contamination, infringement of other mineral rights.

- What environmental and natural resource laws apply? For example, what happens if there are CO$_2$ leaks?

- Who owns the pore space and how are boundaries decided?
Some power and fuel projects are being canceled because of CCS uncertainty.

- On Oct 4, 2007, citing CCS uncertainty, Tampa Electric decides against an IGCC (integrated Gasification Combined Cycle) plant to meet power needs.

But some projects are going forward.

- On March 9, 2007 TXU, after canceling the plans for 10 coal fired generating plants, announces that it will build two IGCC plants in Texas (txucorp.com).
I believe that CO$_2$ contracts when sold as a commodity provide a template for CO$_2$ CCS agreements.

There is much to be learned from the commodity side of the market.

Here are some lessons.
Foremost, as long as the CO₂ is pure, buyers and sellers are not overly concerned about liability issues.

But the quality of CO₂ is a deal-breaker in EOR contracts.
Contracts are very careful to define the substance injected into a reservoir:

- The term "carbon dioxide" means a substance primarily composed of molecules containing one atom of carbon and two atoms of oxygen and containing at least 95 percent by volume of such molecules.
Monitoring is important:

- The carbon dioxide delivered hereunder shall be measured with orifice meters constructed and installed in accordance with the compilation of standards in the *American Petroleum Institute, Manual of Petroleum Standards*, Chapter 14, with any subsequent amendments, revisions and additions which may be mutually acceptable to Seller and Buyer. Computations of pound-mass shall also be made in accordance with said manual.

- A composite sample of the carbon dioxide stream shall be accumulated during each month and analyzed for its composition by gas chromatograph or other methods agreed to by Buyer and Seller, at Seller's expense.
Quality is carefully controlled:

- **Water.** The carbon dioxide shall not contain any free water, and water vapor content shall not exceed 30 pounds per MMcf.

- **Hydrogen Sulphide and Sulfur.** The carbon dioxide shall not contain more than 10 parts by weight of hydrogen sulphide nor more than 35 parts by weight of total sulfur per 1,000,000 parts of carbon dioxide.
Given these specifications the strongest liability clauses go as follows:

- Seller shall be deemed to be in exclusive control and possession of the carbon dioxide prior to delivery hereunder and shall hold Buyer harmless against any injury or damage caused thereby until same shall have been delivered to Buyer at the Point of Delivery, after which title shall pass to Buyer and Buyer shall be deemed to be exclusively in control and possession thereof and shall hold Seller harmless against any injury or damage caused thereby.
These contracts are privately negotiated, terms are kept proprietary. Pricing presents challenges.

In EOR- CO₂ sales contracts that extend for more than a year, the price of CO₂ is tied to the price of oil.
The price adjustment uses the following equation:

\[ P = \frac{c_2}{c_1} \times P_1 \]

- \( P_1 \) is the original (one-year) established price of \( \text{CO}_2 \).
- \( c_1 \) is the baseline price at the beginning of the contract, either crude oil or a broader producer price index (PPI).
- \( c_2 \) is the quarterly adjusted new price of either crude oil or the PPI.
This pervasive pricing practice creates some interesting supply and demand responses in the markets for \( \text{CO}_2 \) and crude oil.

Figure 1. CO$_2$ demand at fixed oil prices and at variable oil prices.
How should prices be configured in a broader CCS context?

I think a two-part tariff scheme would work best where there would be a negotiated price for injection and then a negotiated periodic maintenance charge.
The periodic maintenance charge should be set by the current “cap and trade” price of CO$_2$.

A contract would have periodic storage costs decided by the ECX (European Climate Exchange) or CCX (Chicago Climate Exchange).
- CO$_2$ as a pollutant should trade as a commodity, just like oil, sugar, or cotton.

- Can privately negotiated agreements generate efficient allocations?
Privately negotiated commodity transactions operate “okay” if there is symmetry between the number of buyers and sellers.

<table>
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<th>Instructions</th>
<th>Actual Experiment – Production/Trading Period</th>
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<td>Phase 1</td>
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<td>Phase 2</td>
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<th>Phase 4</th>
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<td><strong>Production</strong></td>
<td><strong>Trading</strong></td>
<td><strong>Earnings</strong></td>
<td></td>
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<tr>
<td>Buyers (4 or 2)</td>
<td>Sellers (4 or 2)</td>
<td>Earnings reported and recorded – Return to Phase 2 - Twenty production/trading periods conducted</td>
<td></td>
</tr>
</tbody>
</table>

- **Production**
  - Experiment Instructions Read and Practice Rounds Conducted
  - Produce Units
  - Wait

- **Trading**
  - Private Negotiation (Three/five bargaining rounds per period - random B/S matches for each bargaining round)
  - Trading in each bargaining round continues until an agree price is reached or seller is out of units
Figure 4. Average trade prices by period and treatment
Figure 2. Average quantities traded by period and treatment
These markets are not helped by additional information “injected” into the trading institution.


Figure 1. Organization of trading cycles for buyers (B) and sellers (S).
Figure 2. Prices - alternative public information treatments
Figure 3. Trades - alternative public information treatments
Any subsidization to CCS, i.e. tax credits paid for undertaking CCS, will be shared between the buyer and seller.

Figure 2. Price by treatment