Preserving Eastern or Offshore Oil for Preventing Green Paradoxes?

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IEW
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Carbon Supply Reducing Policies

Harstad (2012)
- Neither carbon taxes nor tariff policies but purchasing deposits can lead to first best solutions
- Optimal climate policies
  \[\rightarrow\] No green paradoxes

Hoel (2013) (Emissions from the Production Process)
- Purchasing high-value deposits today leads to the weak and can lead to the strong green paradox
- Purchasing low-value deposits today leads to constant present and declining cumulative emissions
- Partial equilibrium model
  \[\rightarrow\] No demand side reactions
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General Structure

Adapted from Eichner & Pethig 2011 and Ritter & Schopf 2013

- The world consists of one fossil fuel exporting country $F$ and two fossil fuel importing countries $A$ and $N$
- The firms in $A$ and $N$ produce the unique commodity, selling it as price takers on the world market, using fossil fuel as the only input
- In each country, there is one lifetime ($t = 1, 2$) utility maximizing household, deriving utility from commodity consumption, owning the firm at home
- The firm in $F$ extracts fossil fuel, selling it as price taker on the world market, facing convex extraction costs in form of the commodity
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Commodity Producers and Households

Commodity producers:

\[
\max_{e_{i1}, e_{i2}} \Pi^i = \sum_t [p_{xt} X^i(e_{it}) - p_{et} e_{it}]
\]

Households:

\[
\max_{x_{i1}, x_{i2}} U(x_{i1}, x_{i2}) = (\alpha_1 x_{i1}^{-b} + \alpha_2 x_{i2}^{-b})^{-\frac{h}{b}}
\]

s.t.

\[
\sum_t p_{xt} x_{it} = \Pi^i* - \sum_t [\mu_t \bar{e}_F t + \nu_t e_{Ft}]
\]

Commodity market:

\[
x^s_{At} + x^s_{Nt} = x_{At} + x_{Nt} + x_{Ft} + x_{Et}
\]

where \(x^s_{it} = X^i(e_{it})\)
Commodity Producers and Households

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  \]
  \[
  \text{s.t. } \sum_t p_{xt} x_{it} = \Pi^i \ast - \sum_t [\mu_t \bar{e}_{Ft} + \nu_t \bar{e}_{Ft}]\]

- Commodity market:
  \[
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  \]
  where \( x_{it}^s = X^i(e_{it}) \)
Commodity Producers and Households

- Commodity producers:
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  \max_{e_{i1}, e_{i2}} \Pi^i = \sum_t [p_{xt}X^i(e_{it}) - p_{et}e_{it}]
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- Households:
  \[
  \max_{x_{i1}, x_{i2}} U(x_{i1}, x_{i2}) = (\alpha_1 x_{i1}^{-b} + \alpha_2 x_{i2}^{-b})^{-\frac{1}{b}}
  \]
  \[
  \text{s.t. } \sum_t p_{xt}x_{it} = \Pi^i - \sum_t [\mu_t \bar{\epsilon}_F t + \nu_t \epsilon_F t]
  \]

- Commodity market:
  \[
  X^s_{At} + X^s_{Nt} = X_{At} + X_{Nt} + X_F + X_{Et}
  \]
  where \(X^i(e_{it})\)
Purchasing high-value deposits:

\[
\max_{e_{F1}, e_{F2}} \Pi^F = \sum_t [p_{et} [e_{Ft} - \bar{e}_{Ft}] + \mu_t \bar{e}_{Ft} - p_{xt} [X^{Et}(e_{Ft}, e_{Ft}) - X^{Et}(\bar{e}_{Ft}, e_{Ft})]]
\]

\[
\tilde{e}_{Ft} = e_{Ft} - \bar{e}_{Ft} = e_{At} + e_{Nt}
\]

where \(X^{Et}(e_{Ft}, e_{Ft}) - X^{Et}(\bar{e}_{Ft}, e_{Ft}) = x_{Et}\)

Purchasing low-value deposits:

\[
\max_{e_{F1}, e_{F2}} \Pi^F = \sum_t [p_{et} [e_{Ft} - e_{Ft}] + \nu_t e_{Ft} - p_{xt} X^{Et}(e_{Ft} - e_{Ft}, e_{Ft} - e_{Ft})]
\]

\[
e_{Ft} = e_{Ft} - e_{Ft} = e_{At} + e_{Nt}
\]

where \(X^{Et}(e_{Ft} - e_{Ft}, e_{Ft} - e_{Ft}) = x_{Et}\)
Fossil Fuel Extractor

- Purchasing high-value deposits:

\[
\max_{e_{F1}, e_{F2}} \Pi^F = \sum_t [p_{et}[e_{Ft} - \bar{e}_{Ft}] + \mu_t \bar{e}_{Ft} - p_{xt}[X^{Et}(e_{Ft}, e_{Ft}) - \bar{X}^{Et}(\bar{e}_{Ft}, e_{Ft})]]
\]

\[
\tilde{e}_{Ft} = e_{Ft} - \bar{e}_{Ft} = e_{At} + e_{Nt}
\]

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- Purchasing low-value deposits:

\[
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\]

\[
e_{Ft} = e_{Ft} - e_{Ft} = e_{At} + e_{Nt}
\]

where \( X^{Et}(e_{Ft} - e_{Ft}, e_{Ft} - \bar{e}_{Ft}) = x_{Et} \)
Graphical Analysis ($d\bar{e}_{F1} > 0$)
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Analytical Results ($d\overline{e}_{F1} > 0$)

Due to purchasing high-value deposits in the first period

- the emissions in the first period do not decline by more than $d\overline{e}_{F1}$
- and the cumulative emissions do not decline by more than $d\overline{e}_{F1}$ if $\Gamma_1 \geq 0$, and they decline by more than $d\overline{e}_{F1}$ if $\Gamma_1 < 0$

$$\Gamma_1 \geq 0 \text{ iff } \frac{e_{F1}\eta_{F1,2}}{e_{N2}\eta_{N2}} + \frac{e_{F1}\eta_{F1,2}}{e_{F2}\eta_{F2,2}} \geq 1$$
Conditions for the Green Paradoxes ($d\bar{e}_{F1} > 0$)

Purchasing high-value deposits in the first period leads to the Green Paradoxes under the following conditions:

\[
\begin{align*}
\frac{d\tilde{e}_{F1}}{d\bar{e}_{F1}} > 0 \iff \sigma &< \alpha \cdot \frac{p_{x2}[X_{eF1} - \bar{X}_{eF1}]}{p_{e1}} \cdot \frac{\mu_1 e_{F1} \bar{\eta}_{F1,1}}{x_{A1} + x_{N1} - x_{E1}} \\
\frac{d\tilde{D}}{d\bar{e}_{F1}} > 0 \iff \sigma &< \beta \cdot \frac{p_{x2}[X_{eF1} - \bar{X}_{eF1}]}{p_{e1}} \cdot \frac{\mu_1 e_{F1} \bar{\eta}_{F1,1}}{x_{A1} + x_{N1} - x_{E1}} 
\end{align*}
\]

\[
\tilde{D}(\bar{e}_{F1}, \bar{e}_{F2}) = \left( c_1 \bar{e}_{F1}^d + c_2 (\bar{e}_{F1} + \bar{e}_{F2})^d \right)^{\frac{l}{a}}
\]
Analytical Results ($d\bar{e}_{F2} > 0$)

Due to purchasing high-value deposits in the second period

- the weak green paradox occurs if and only if the present fossil fuel price falls ($dp_{e1} < 0$)
- and the cumulative emissions do not decline by more than $d\bar{e}_{F2}$ if $\Gamma_1 \leq 0$, and they decline if $\Gamma_1 > 0$ and $\bar{\Gamma}_2 \geq 0$

$$\bar{\Gamma}_2 \geq 0 \text{ iff } \frac{e_{F2}\bar{\eta}_{F2,1}}{e_{N1}|\eta_{N1}|} + \frac{e_{F2}\bar{\eta}_{F2,1}}{e_{F1}\bar{\eta}_{F1,1}} \geq 1$$
Motivation

The Model

Eastern Oil

Offshore Oil

Conclusion

Acting Tomorrow

Conditions for the Green Paradoxes \((d\bar{e}_{F2} > 0)\)

Purchasing high-value deposits in the second period leads to the Green Paradoxes under the following conditions:

\[
\frac{d e_{F1}}{d \bar{e}_{F2}} > 0 \quad \Leftrightarrow \quad \sigma > \frac{p_{x2} [X^{E2}_{eF1} - \bar{X}^{E2}_{eF1}]}{p_{e1}} \cdot \frac{\mu_{2eF2}\eta_{F2,2}}{p_{x2}(x^{s}_{A2} + x^{s}_{N2} - x_{E2})} \left(\frac{e_{F2}\eta_{F2,1}}{e_{N2}\eta_{N2}} + \frac{e_{F2}\eta_{F2,1}}{e_{F2}\eta_{F2,2}}\right)^{-1}
\]

\[
\frac{d \bar{D}}{d \bar{e}_{F2}} > 0 \quad \Leftrightarrow \quad \sigma \geq \frac{p_{x2} [X^{E2}_{eF1} - \bar{X}^{E2}_{eF1}]}{p_{e1}} \cdot \frac{\mu_{2eF2}\eta_{F2,2}}{p_{x2}(x^{s}_{A2} + x^{s}_{N2} - x_{E2})} \left(\frac{-\bar{r}_{2}^{D}}{p_{e1}e_{N1}\eta_{N1}} - \frac{\bar{r}_{1}^{D}}{p_{e2}e_{N2}\eta_{N2}} + \frac{\bar{\Theta}}{\bar{e}_{F2}\eta_{F2,2}} \frac{\mu_{2eF2}\eta_{F2,2}}{p_{x2}(x^{s}_{A2} + x^{s}_{N2} - x_{E2})}\right) \quad \text{if} \quad \bar{r}_{2}^{D} \leq 0
\]
Graphical Analysis ($de_{F1} > 0$)
Graphical Analysis ($d e_{F_1} > 0$)
Graphical Analysis (de_{F1} > 0)
**Motivation**

**The Model**

**Eastern Oil**

**Offshore Oil**

**Conclusion**

**Acting Today**

**Graphical Analysis (d_\text{e}_{F1} > 0)**

![Graphical Analysis Diagram](image)
Motivation

The Model

Eastern Oil

Offshore Oil

Conclusion

Acting Today

Analytical Results ($d_{\text{e}F1} > 0$)

Due to purchasing low-value deposits in the first period

- the commodity price in period two falls ($d\rho_{x2} < 0$)
- the present fossil fuel price rises ($d\rho_{e1} > 0$)
- the emissions in the first period decline by less than $d_{\text{e}F1}$
- and the cumulative emissions decline and decline by more than $d_{\text{e}F1}$ if $\Gamma_1 < 0$
Analytical Results ($d_{eF2} > 0$)

Due to purchasing low-value deposits in the second period

- the commodity price in period two rises ($dp_{x2} > 0$)
- the fossil fuel prices rise ($dp_{et} > 0$)
- the emissions in the first period decline
- and the cumulative emissions decline and can decline by more than $d_{eF2}$ if $\Gamma_1 > p_{e2}$
Conclusion

- Purchasing high-value deposits might lead to an increase in cumulative and present emissions.
  - The conditions for the green paradoxes are similar to those in case of carbon demand reducing policies.
- Purchasing low-value deposits does lead to a decrease in cumulative and present emission.
- In general, purchasing deposits might also lead to negative cumulative carbon leakage and, by acting tomorrow, to negative present carbon leakage.
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For Further Reading

- Thomas Eichner & Rüdiger Pethig. 
  Carbon Leakage, the Green Paradox and Perfect Future Markets. 

- Bård Harstad. 
  Buy Coal! A Case for Supply-Side Environmental Policy. 

- Michael Hoel. 
  Supply Side Climate Policy and the Green Paradox. 

- Hendrik Ritter & Mark Schopf. 
  Unilateral Climate Policy: Harmful or even Disastrous? 
Fossil Fuel Market - Acting Today

On the fossil fuel market, purchasing high-value or low-value deposits today affects the present and the cumulative extraction:

\[
\begin{align*}
\text{d} \tilde{e}_{F1} &= - \frac{\Gamma_0 - p_{e1} [p_{e2} + p_{x2} X_{eF2eF2} e_{N2} | \eta N2 |]}{\Gamma_0} \text{d} \tilde{e}_{F1} \\
&\quad - \frac{[X_{eF1}^{E2} - X_{eF1}^{E2}] e_{N1} | \eta N1 | [p_{e2} + p_{x2} X_{eF2eF2} e_{N2} | \eta N2 |]}{\Gamma_0} \text{d} p_{x2} \\
\text{d} \tilde{e}_{F\Sigma} &= - \frac{\Gamma_0 - p_{e1} \Gamma_1}{\Gamma_0} \text{d} \tilde{e}_{F1} - \frac{[X_{eF1}^{E2} - X_{eF1}^{E2}] e_{N1} | \eta N1 | \Gamma_1}{\Gamma_0} \text{d} p_{x2} \\
\text{d} e_{F1} &= - \frac{\Gamma_0 - p_{e1} [p_{e2} + p_{x2} X_{eF2eF2} e_{N2} | \eta N2 |]}{\Gamma_0} \text{d} e_{F1} \\
&\quad - \frac{X_{eF1} e_{N1} | \eta N1 | [p_{e2} + p_{x2} X_{eF2eF2} e_{N2} | \eta N2 |]}{\Gamma_0} \text{d} p_{x2} \\
\text{d} e_{F\Sigma} &= - \frac{\Gamma_0 - p_{e1} \Gamma_1}{\Gamma_0} \text{d} e_{F1} - \frac{X_{eF1} e_{N1} | \eta N1 | \Gamma_1}{\Gamma_0} \text{d} p_{x2}
\end{align*}
\]
On the fossil fuel market, purchasing high-value or low-value deposits tomorrow affects the present and the cumulative extraction:

\[
\begin{align*}
\mathrm{d}e_{F1} &= -\frac{p_{e2}p_{x2}X^{E2}_{eF1eF2}e_{N1}\vert\eta_{N1}\vert - p_{x2}\bar{X}^{E2}_{eF1\bar{e}F2}e_{N1}\vert\eta_{N1}\vert \left[ p_{e2} + p_{x2}X^{E2}_{eF2eF2}e_{N2}\vert\eta_{N2}\vert \right]}{\Gamma_0} \mathrm{d}\bar{e}_{F2} \\
&\quad - \frac{\left[ X^{E2}_{eF1} - \bar{X}^{E2}_{eF1} \right] e_{N1}\vert\eta_{N1}\vert \left[ p_{e2} + p_{x2}X^{E2}_{eF2eF2}e_{N2}\vert\eta_{N2}\vert \right]}{\Gamma_0} \mathrm{d}p_{x2} \\
\mathrm{d}\tilde{e}_{F\Sigma} &= -\frac{\Gamma_0 - p_{e2}\Gamma_2 - p_{x2}\bar{X}^{E2}_{eF1\bar{e}F2}e_{N1}\vert\eta_{N1}\vert \Gamma_1}{\Gamma_0} \mathrm{d}\bar{e}_{F2} - \frac{\left[ X^{E2}_{eF1} - \bar{X}^{E2}_{eF1} \right] e_{N1}\vert\eta_{N1}\vert \Gamma_1}{\Gamma_0} \mathrm{d}p_{x2} \\
\mathrm{d}e_{F1} &= -\frac{p_{e2}p_{x2}X^{E2}_{eF1eF2}e_{N1}\vert\eta_{N1}\vert}{\Gamma_0} \mathrm{d}\bar{e}_{F2} \\
&\quad - \frac{X^{E2}_{eF1}e_{N1}\vert\eta_{N1}\vert \left[ p_{e2} + p_{x2}X^{E2}_{eF2eF2}e_{N2}\vert\eta_{N2}\vert \right]}{\Gamma_0} \mathrm{d}p_{x2} \\
\mathrm{d}\tilde{e}_{F\Sigma} &= -\frac{\Gamma_0 - p_{e2}\Gamma_2}{\Gamma_0} \mathrm{d}\bar{e}_{F2} - \frac{X^{E2}_{eF1}e_{N1}\vert\eta_{N1}\vert \Gamma_1}{\Gamma_0} \mathrm{d}p_{x2}
\end{align*}
\]
Commodity Market

On the commodity market, purchasing high-value or low-value deposits affects the commodity price in period two:

\[ \frac{dp_{x2}}{p_{x2}} = \frac{p_{x2}}{\sigma} \left( \frac{\Theta}{\sigma} \frac{\mu_1}{x_{A1}^s + x_{N1}^s - x_{E1}} \frac{d\tilde{e}_{F1}}{\tilde{e}_{F1}} + \frac{\mu_2}{p_{x2} (x_{A2}^s + x_{N2}^s - x_{E2})} d\tilde{e}_{F2} \right) \]

\[ \frac{dp_{x2}}{p_{x2}} = \frac{p_{x2}}{\sigma} \left( \left( \frac{\Theta}{\sigma} + \frac{\nu_1}{x_{A1}^s + x_{N1}^s - x_{E1}} \right) \frac{d\tilde{e}_{F1}}{\tilde{e}_{F1}} - \frac{\nu_2}{p_{x2} (x_{A2}^s + x_{N2}^s - x_{E2})} \frac{d\tilde{e}_{F2}}{\tilde{e}_{F2}} \right) \]

\[ \bar{\Theta} = \frac{p_{x2} [x_{E2}^{e_{F1}} - x_{e_{F1}}^{E2}]}{x_{A1}^s + x_{N1}^s - x_{E1}} + \frac{p_{x2} [x_{e_{F1}}^{E2} - x_{e_{F1}}^{E2}]}{p_{x2} (x_{A2}^s + x_{N2}^s - x_{E2})} \quad \text{and} \quad \Theta = \frac{p_{x2} [x_{e_{F1}}^{E2}]}{x_{A1}^s + x_{N1}^s - x_{E1}} + \frac{p_{x2} [x_{E2}^{e_{F1}}]}{p_{x2} (x_{A2}^s + x_{N2}^s - x_{E2})} \]