The Grey Paradox: How Fossil-fuels Owners Can Benefit From Carbon Regulation.

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Introduction

OPEC 's viewpoint on carbon taxation:

- *"Especially vulnerable are the oil producing developing countries, which are mainly OPEC member countries, [...], it is important to ensure that measures taken to combat climate change do not place an unfair burden on oil." (Dr R. Lukman, OPEC Secretary General, COP6 of the UNFCCC, The Hague, 2000.)*
- **Carbon taxation would decrease OPEC 's profits:**
  - reduction in oil demand;
  - transfer of rents from oil exporting countries to importing countries that collect the tax.

$\Longrightarrow$ OPEC 's claims for compensations at international negotiations.

Does carbon taxation reduce OPEC 's profits?

Introduction

Main question:

- How optimal carbon taxation impacts profits of fossil-fuels owners?

Main result (the Grey Paradox):

- The profits of owners of a fossil fuel may increase thanks to optimal carbon taxation, if a dirtier abundant resource is, or will be, also used, even if tax revenues are not redistributed to them.

Intuition:

- Rare resources like conventional oil, or gas are likely to be exhausted unless the regulation is very strict. -> unchanged cumulative extraction.
- They are less polluting than some abundant fossil fuels (coal, unconv. oil). Their after-tax price may increase more than the carbon tax, rising up profits of their owners.
  - A carbon tax increases the price of these resources by increasing the price of their substitutes (competition effect).
  - It transfers rents from exporting countries to importing countries that collect the tax (capture effect).

Introduction

- **Fossil fuels are not shared equally in the world** (BGR 2012)

	Oil			Natural gas			Coal
	Total	*Conv.*	*Unconv.*	Total	*Conv.*	*Unconv.*	
OPEC-Gulf	49.6	*63.8*	*0.0*	39.8	*40.7*	*0.0*	0.1
OECD 2000	16.7	*5.3*	*56.1*	9.1	*7.1*	*92.3*	43.2
World	100	*100*	*100*	100	*100*	*100*	100

- **Countries with large reserves of gas or conv. oil have low reserves of coal or unconv. oil and vice et versa** (except Russia).
  - oil: 85% in Canada, Venezuela, Saudi, Iran, Iraq, Kuweït, UAE; gas: 57% in Russia, Iran, Qatar; coal: 75% in USA, Russia, China, Australia, India.
- **Asymmetric impacts of carbon taxation on countries because of resources endowments?**
  - Can this explain countries' position regarding worldwide carbon taxation? Canada withdrew from the Kyoto Protocol in 2011 after the boom in oil sands production (x10 over 2007-2011).

Related Literature

Extraction of natural resources:

- Differentiated by their extraction cost
  - Hotelling (1931), Herfindahl (1967).
- or/and differentiated by their pollution content
  - Chakravorty et al. (2006), Chakravorty et al. (2008)), van der Ploeg & Withagen (2012).

Capturing rents from fossil fuels:

- Bergstrom (1982), Brander & Djajic (1983), Liski & Tahvonen (2004).

Simulations of energy-economy models:

- Barnett et al. (2004), literature estimating that OPEC's profits will decrease, except Persson et al. (2007).
- Difficult to understand the conditions under which profits of owners of some polluting resources can increase when pollution is taxed.

The Model: assumptions and notations

Hotelling model with three energy resources:

- an *exhaustible* polluting resource, $x_e(t)$, X_e^0, θ_e, c_e;
- a *dirtier* abundant resource, $x_d(t)$, $\theta_d > \theta_e$, c_d;
- a clean *backstop*, $x_b(t)$, $\theta_b = 0$, $c_b > max(c_e, c_d)$.

Carbon ceiling over the CO_2 concentration, $\bar{Z}$

- CO_2 emissions: $\theta_e x_e(t) + \theta_d x_d(t)$.

Decentralization of the optimal extraction path (that maximizes the discounted social surplus)

- The optimal extraction path is decentralized by a tax on CO_2 emissions, perceived as credible;
- Tax revenues are not redistributed to owners of polluting resources;
- Perfect competition among resources owners, profits come from the scarcity of the exhaustible resource.

Optimal prices

Scarcity rent:

- $\lambda_e(t)$: the current scarcity rent of the exhaustible resource (Hotelling 1931):

$$\lambda_e(t) = \lambda_e^0 e^{rt}.$$

Shadow cost of CO_2:

- $\mu(t)$: the current shadow cost of pollution. If the ceiling does not – but will – bind:

$$\mu(t) = \mu^0 e^{rt}.$$

Optimal prices of resources:

$$\begin{aligned} p_e(t) &= c_e + \lambda_e(t) + \theta_e \mu(t); \\ p_d(t) &= c_d + \theta_d \mu(t); \\ p_b(t) &= c_b. \end{aligned}$$

Ordering resources extraction

Switch to the clean backstop:

- The maximum amount of pollution put in the atmosphere equals $\bar{Z} - Z^0$;
- There is a switch from polluting resources to the clean backstop when the CO_2 concentration reaches the ceiling, $\bar{Z}$.

Ordering the extraction of the polluting resources:

- The resource with the lowest extraction cost is either used first or not used at all (in the second case, it must be more polluting than the other resource), close to Herfindahl (1967).
- We assume $\theta_e < \theta_d$, two cases: $c_e < c_d$ or $c_e > c_d$.

Decentralization, carbon tax and profits

- The optimal extraction path is decentralized by a tax on CO_2 emissions, perceived as credible;
- **If both polluting resources are used and the exhaustible one becomes exhausted** (relevant case),
  - **the only way to decentralize the optimum is to set a carbon tax equal to the pollution cost.**
    $\Longrightarrow$ limited capacity to capture rents.
  - Recall that $p_e(t) = c_e + \lambda_e(t) + \theta_e \mu(t)$. **The current marginal profit equals the scarcity rent** $\lambda_e(t)$.
  - Cumulative discounted profits simply write: $\lambda_e^0 {X_e}^0$.

The exhaustible resource is the cheapest to extract: $c_e < c_d$

- If $c_e < c_d$, the exhaustible resource is necessarily used since it is cheaper to extract and less polluting than the dirty backstop. It becomes exhausted iff. $X_e^0 < \frac{\bar{Z}-Z^0}{\theta_e}$.
- The solution $\{\lambda_e^0, \mu^0, t^s, \underline{t}\}$ satisfies:

$$
\begin{aligned}
c_e + \lambda_e^0 e^{rt^s} + \theta_e \mu^0 e^{rt^s} &= c_d + \theta_d \mu^0 e^{rt^s} && (1)\\
c_d + \theta_d \mu^0 e^{r\underline{t}} &= c_b && (2)\\
\int_0^{t^s} D(c_e + \lambda_e^0 e^{rt} + \theta_e \mu^0 e^{rt})dt &= X_e^0 && (3)\\
\theta_e X_e^0 + \int_{t^s}^{\underline{t}} \theta_d D(c_d + \theta_d \mu^0 e^{rt})dt &= \bar{Z} - Z^0. && (4)
\end{aligned}
$$

The exhaustible resource is the cheapest to extract: $c_e < c_d$

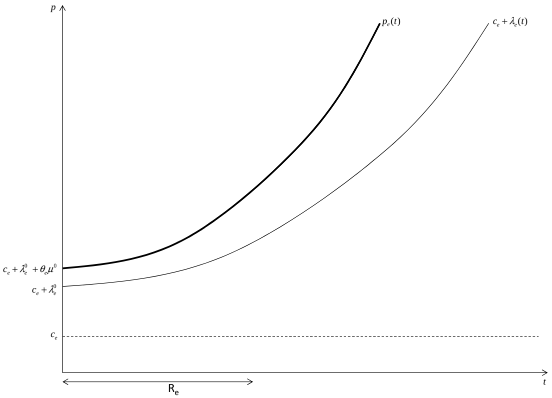

Figure: Energy price path when $c_e < c_d$

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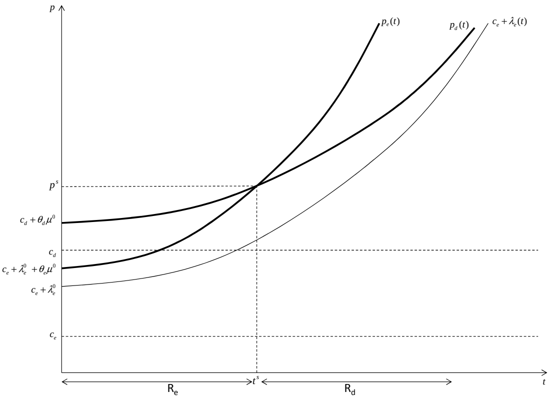

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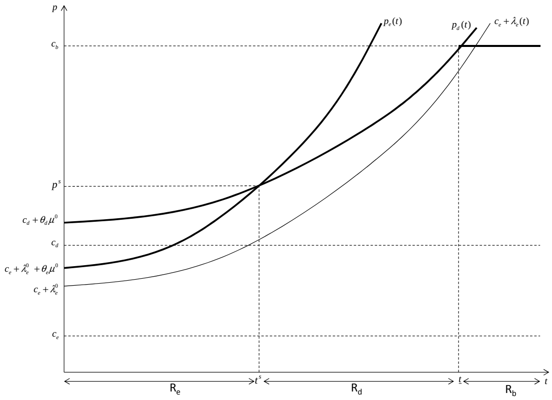

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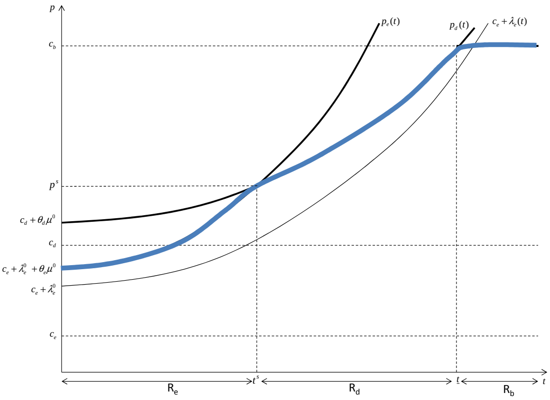

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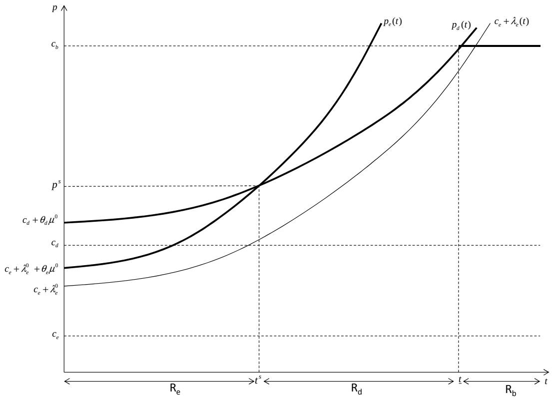

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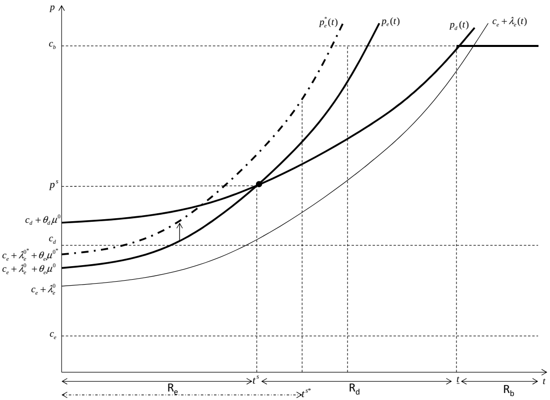
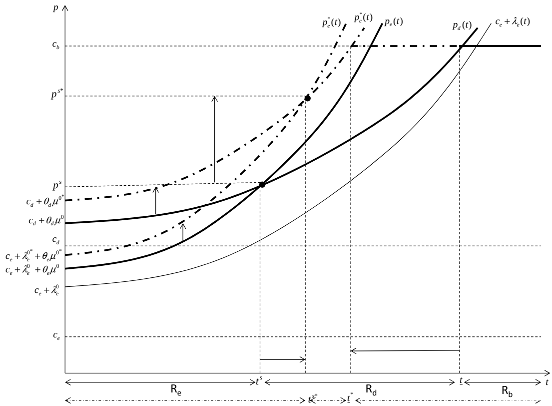


Figure: New energy price after a fall of the ceiling, $c_e < c_d$

The exhaustible resource is the cheapest to extract: $c_e < c_d$



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The exhaustible resource is the cheapest to extract: $c_e < c_d$

Tightening the carbon constraint yields:

- **an increase of the long-term price of the exhaustible resource** (transition price between the resources) that would increase profits if the carbon tax on this resource was left unchanged = the **"competition effect"**. It writes $\delta_1 \lambda_e^0 = \frac{e^{-rt^s}}{\lambda^s + \theta_e \mu^s} \left(\frac{D(p^s)}{D(p^0)} \lambda^s + \theta_e \mu^s \right) dp^s$.
- **an increase of the carbon tax on the exhaustible resource** that would decrease profits if the switch price remained unchanged = the **"capture effect"**. It writes $\delta_2 \lambda_e^0 = -\theta_e e^{-rt^s} d\mu^s$. The new scarcity rent, λ_e^{0*}, is thus lower than the value of the virtual scarcity rent when only the competition effect is taken into account.

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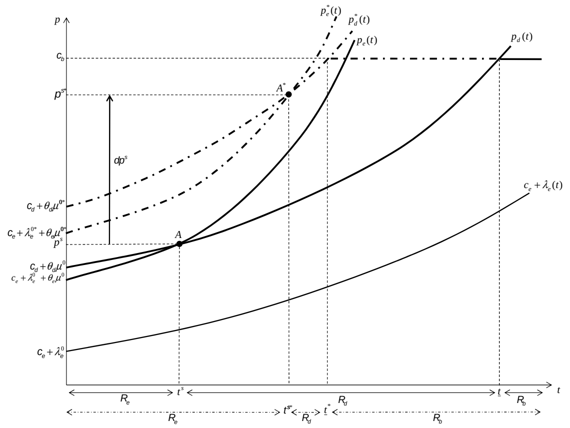

Figure: Profits after a fall of the ceiling with only the competition effect, $c_e < c_d$

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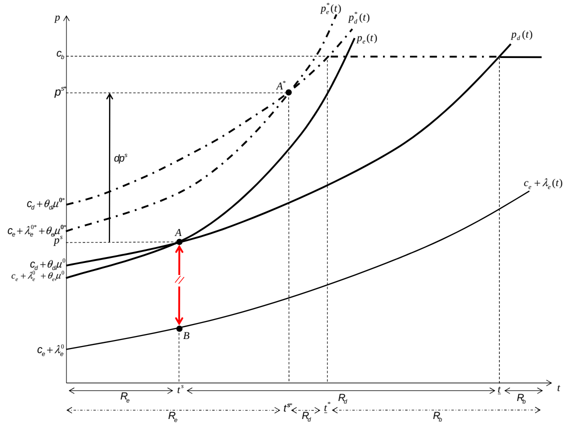

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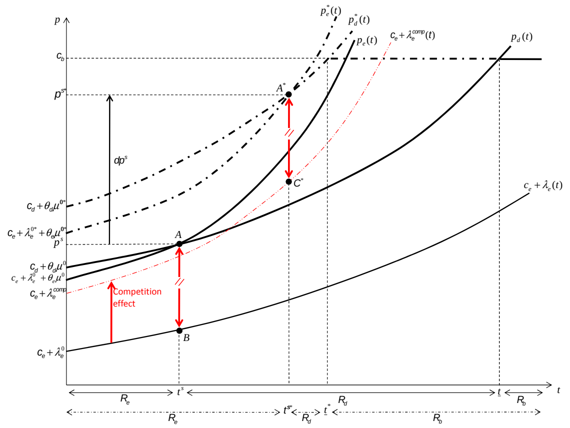

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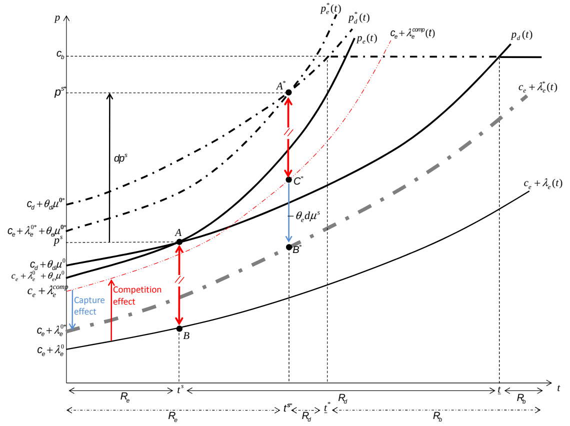

Figure: Profits after a fall of the ceiling, $c_e < c_d$: the Grey Paradox occurs

The exhaustible resource is the cheapest to extract: $c_e < c_d$

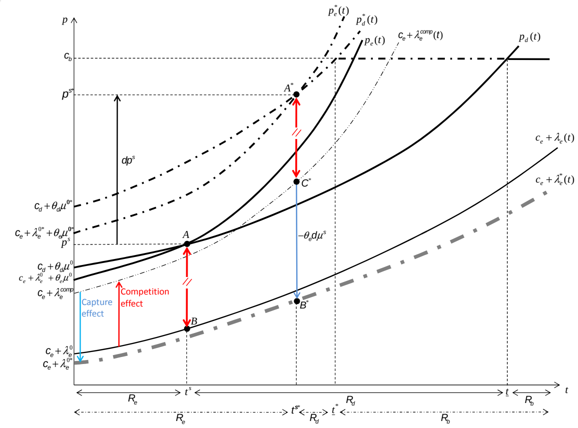

Figure: Profits after a fall of the ceiling, $c_e < c_d$: no Grey Paradox

The exhaustible resource is the cheapest to extract: $c_e < c_d$

- **The overall effect of a fall of the ceiling is ambiguous.**
- Combining both effects, we find that the **profits of owners of the exhaustible resource increase as the ceiling is lowered if and only if**

$$\frac{D(p(t^s))}{D(p(0))}\frac{\theta_d}{\theta_e} + (\theta_d - \theta_e)\frac{\mu^0}{\lambda_e^0} > 1.$$

- It holds i.e **profits of the exhaustible-resource owners increase after a fall of the ceiling if** any of the following holds:
  - **its demand elasticity is low enough**;
  - **its extraction cost is close enough to that of the dirty backstop**;
  - **its initial stock is small enough**;
  - **its pollution content is low enough** (compared to that of the dirty backstop).

The abundant polluting resource is the cheapest to extract: $c_e > c_d$

- Without environmental regulation, the exhaustible resource would not be used if $c_e < c_d$.
- Moving from a situation where the exhaustible resource is not used to a situation where it is exhausted, profits must increase at some point.
- Both resources are used and the exhaustible one becomes exhausted (the dirtier resource used first) if and only if $c_b > \frac{\theta_d c_e - \theta_e c_d}{\theta_d - \theta_e}$, and $X_e^0 < \min\{X^*, \frac{\bar{Z} - Z^0}{\theta_e}\}$.
- **If both resources are used and the exhaustible resource becomes exhausted, tightening the ceiling constraint increases the profits of owners of the exhaustible resource** $\left(\frac{d\lambda_e^0}{d\bar{Z}} < 0.\right)$

Extension: two polluting exhaustible resources

- Different fossil fuels and different grades of resources more or less polluting or expensive to extract (or even different characteristics for each deposit).
- Modelization: two polluting exhaustible resources are available in addition to the dirty and the clean backstops.

$\Longrightarrow$ Similar results.

- Who will win the most or loose the least from an increase of the tax?
- Owners of a polluting resource can benefit more from carbon regulation than owners of a cleaner resource if a dirtier resource is or will be used.
- Application to the transportation sector with conv. inshore oil, conv. offshore oil and unconv. oil: OPEC-Gulf/Venezuela/Canada.
- Divergence of incentives within OPEC (OPEC-Gulf vs. Venezuela)?

Other extensions

- Two-sector economy with resources specialization
- Increasing extraction costs with cumulative extraction
- Carbon capture and storage at constant cost
- Fall of the cost of the clean backstop
- Resource profits used in R&D to reduce extraction costs or to explore the earth's crust to find new deposits

$\Longrightarrow$ Similar results.

Conclusions

- Profits of owners of polluting exhaustible resources may increase thanks to (optimal) carbon taxation if a dirtier abundant resource is also used, even if tax revenues are not redistributed to them (the Grey Paradox).
- Two effects: a competition effect and a rent capture effect.
- Role of resources endowments, extraction costs, demand elasticity, and pollution contents are analyzed.
- Extensions: CO_2 capture, two sectors, several exhaustible polluting resources, increasing extraction costs, technological progress in the clean backstop, investments of profits.
- Debate over compensations for OPEC.
- Potential heterogeneous incentives within OPEC (OPEC-Gulf vs. Venezuela)
- Major coal or unconventional-oil exporters are likely to remain insensitive to pro-mitigation arguments.
- Need of a deep empirical investigation of the Grey Paradox.

Thank you for your attention.

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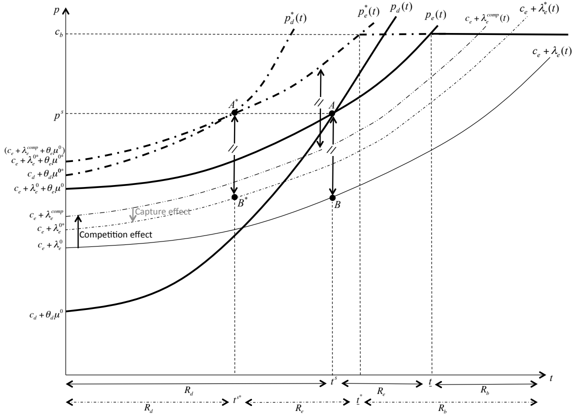

Figure: Profits after a fall of the ceiling, $c_e > c_d$: the Grey Paradox occurs

- World reserves, resources and pollution contents of fossil fuels in 2011.

Fossil fuel	Reserves (EJ)	Resources (EJ)	Pollution content (gCO_2e/MJ)
Oil	9 032	19 495	
Conv.	*7014*	*6 637*	*92*
Unconv.	*2018*	*12 858*	106
Natural gas	7 415	29 842	
Conv.	*7 240*	*11 671*	*76*
Unconv.	*175*	*18 171*	*72*
Coal	21 952	473 893	110

Data for reserves and resources from BGR (2012). Pollution contents are life-cycle greenhouse gas contents from Burnham et al. (2012). EJ = exajoules; MJ = megajoules.

	Oil			Natural gas			Coal
	Total	*Conv.*	*Unconv.*	Total	*Conv.*	*Unconv.*	
Europe	1.0	*1.3*	*0.0*	2.2	*2.3*	*0.0*	8.6
CIS	8.1	*10.4*	*0.0*	31.9	*32.7*	*1.0*	20.7
Africa	8.3	*10.7*	*0.0*	7.5	*7.7*	*0.0*	3.5
Middle East	50.2	*64.7*	*0.0*	40.8	*41.8*	*0.0*	0.1
Austral-Asia	2.6	*3.4*	*0.0*	8.6	*8.2*	*27.0*	40.3
North America	15.5	*3.8*	*56.1*	5.0	*3.4*	*72.0*	25.4
Latin America	14.3	*5.8*	*43.9*	3.9	*4.0*	*0.0*	1.4
World	100	*100*	*100*	100	*100*	*100*	100
OPEC 2009	69.3	*76.6*	*43.9*	48.5	*49.7*	*0.0*	0.2
OPEC-Gulf	49.6	*63.8*	*0.0*	39.8	*40.7*	*0.0*	0.1
OECD 2000	16.7	*5.3*	*56.1*	9.1	*7.1*	*92.3*	43.2

Calculus using data from BGR (2012).

Table: Share of world fossil-fuel reserves by world region and economic policy organization in 2011

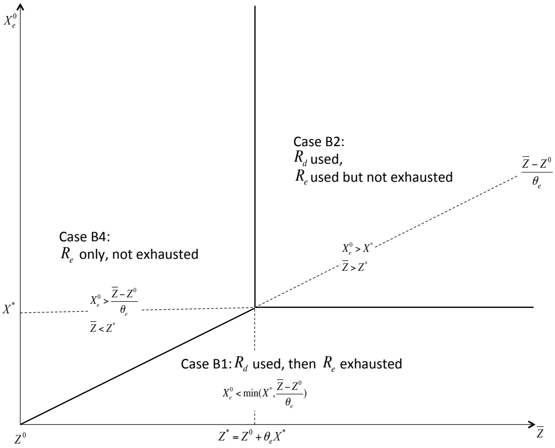

Figure: Characterization of the different cases when $c_e > c_d$

The Model: the social planner maximization program

The **social planner** seeks to find the extraction path $\{x_e(t), x_d(t), x_b(t)\}$ which maximizes the net discounted social surplus:

$$\int_0^{\infty} e^{-rt} \left(u(x_e(t) + x_d(t) + x_b(t)) - c_e x_e(t) - c_d x_d(t) - c_b x_b(t) \right) dt$$

s.t.

$$\begin{aligned} \dot{X}_e(t) &= -x_e(t) \\ \dot{Z}(t) &= \theta_e x_e(t) + \theta_d x_d(t) \\ Z(t) &\leq \bar{Z} \\ X_e(t), x_i(t) &\geq 0 \end{aligned}$$

with Z^0, X_e^0 given.

Extension 1: CO_2 capture

- Some technological options allow keeping on using fossil fuels without drastically increasing carbon concentration.
- Among these options, Carbon Capture and Storage (CCS) technology is one of the most promising.
- *"Without CCS, overall costs to reduce emissions to 2005 levels by 2050 increase by 70%"* (IEA (2009)).
- Modelisation: possibility to capture CO_2 emissions at constant marginal constant.

$\Longrightarrow$ Similar results.

Extension 2: a two-sector economy

	Coal	Oil	Gas
Transports	.	93.5%	.
Industries	28.1%	14.0%	19.4%
Electricity	46.9%	5.9%	21.9%
Total	27.2%	32.9%	20.0%

Table: Fossil-fuels use by sector in 2009, (IEA 2011)

- Modelization: two sectors (power generation and transportation). The dirty backstop and the exhaustible resource are perfect substitute in the power sector. In the transportation sector, the dirty backstop needs to be transformed at a positive unitary cost.
- Energy mix in some cases + sequential sectoral use of the resources.

$\Longrightarrow$ Similar results.

Extension 3: two polluting exhaustible resources

- Fossil fuels: coal, oil, gas. Different grades of resources more or less polluting or expensive to extract. and different characteristics for each deposit. Oil: conv. oil = 30% of world resources; the rest is unconv. oil (composed of extra-heavy oil, bituminous sands etc.).
- Modelization: two polluting exhaustible resources are available in addition to the dirty and the clean backstops.

$\Longrightarrow$ Similar results.

- Who will win the most or loose the least from an increase of the tax?
- Owners of a polluting resource can benefit more from carbon regulation than owners of a cleaner resources if a dirtier resource is or will be used.
- Application to the transportation sector with conv. inshore oil, conv. offshore oil and unconv. oil.
- Divergence of incentives within OPEC (OPEC-Gulf vs. Venezuela)?

Extension 4: increasing extraction costs

- Increasing extraction costs with cumulative extraction.
  - Decrease of the pressure in wheels for instance
  - Extraction of a resource from different deposits (Herfindahl (1967))
- Framework similar to the one with different exhaustible resources. A resource with an extraction cost that increase with cumulative extraction can be considered as a set of resources with similar pollution contents but with different extraction costs, the cheaper resources being used first.

$\Longrightarrow$ Similar results.

Other extensions

- The clean-backstop cost can fall over time -> similar results.
- Resource profits can be used in R&D to reduce extraction costs or to explore the earth's crust to find new deposits -> exacerbates the impact of a fall of the carbon ceiling on total profits in our model.
- A final remark is that OPEC domestic markets represented 9.8% of world oil consumption and 23.3% of their own production in 2011. They amount to 12.8% of world gas consumption and 69.8% of their own production (BGR 2012). OPEC countries can use strategies, for instance exempting their domestic market from the tax, to increase their profits or reduce their losses. Allowing for such strategies would clearly make the emergence of the Grey Paradox more likely.