ORDECSYS

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Impact of uncertain CCS deployment on EU climate negotiations[1]

Frédéric Babonneau, Alain Haurie and Marc Vielle

fbabonneau@ordecsys.com

34th IEW - Abu Dhabi
June 3-5, 2015

[1]Research supported by the Qatar National Research Grant 6 1035 5 126.

Context

The facts:

- Climate policy is one of the corner stones of European Union (EU) policy
- European Commission has defined a roadmap with an objective of 80% GHG reduction in 2050 compared to 1990 levels
- Carbon Capture and Sequestration technologies are considered as potential backstop technologies (up to 14% of total abatements according to IEA)
- CCS deployment is highly uncertain with technical, social and legislative issues

Questions:

1. How to share the burden of the GHG target? How to design a fair agreement among EU countries?
2. How each country will use its allocations on the horizon 2020-2050? What will be the associated costs for each country?
3. What impacts of CCS uncertainty on such agreements?

Context

The facts:

- Climate policy is one of the corner stones of European Union (EU) policy
- European Commission has defined a roadmap with an objective of 80% GHG reduction in 2050 compared to 1990 levels
- Carbon Capture and Sequestration technologies are considered as potential backstop technologies (up to 14% of total abatements according to IEA)
- CCS deployment is highly uncertain with technical, social and legislative issues

Questions:

1. How to share the burden of the GHG target? How to design a fair agreement among EU countries?
2. How each country will use its allocations on the horizon 2020-2050? What will be the associated costs for each country?
3. What impacts of CCS uncertainty on such agreements?

A noncooperative dynamic game

Assumptions:

1. **A safety emissions budget** *Bud* is distributed among the players. Let $\theta_j \in (0,1)$ be the share of player j, with $\sum_{j=1}^{m} \theta_j = 1$.
2. **A competitive market for emissions permits**, which clears at each period. Let ω_j^t be the vector of permits for country j at period t.
3. **CCS penetration**. We denote ccs_j^t the amount of emissions of country j sequestered at period t at cost C^t and $\overline{ccs}_j^t$ the upper bound for sequestration for country j at period t.

Model: Then we consider the game where each player j controls the permit allocations schedule $(\omega_j^t : t = 0, \dots, T-1)$ with $\Omega^t = \sum_{j=1}^{m} \omega_j^t$ and tries to achieve

$$\max_{\omega_j, ccs_j \le \overline{ccs}_j} \left\{ \sum_{t=0}^{T-1} \beta_j^t (\pi_j^t(\mathbf{e}_j^t(\Omega^t)) + p^t(\Omega^t)(\omega_j^t - \mathbf{e}_j^t(\Omega^t) + \mathrm{ccs}_j^t) - C^t \mathrm{ccs}_j^t \right\},$$

subject to actions chosen by the other players and under the budget sharing constraint

$$\sum_{t=0}^{T-1} \omega_j^t \le \theta_j \mathrm{Bud}. \tag{1}$$

Here $\pi_j^t(e_j^t)$ represents the economic benefits obtained from emissions by country j, at time t.

A noncooperative dynamic game

Assumptions:

1. **A safety emissions budget** *Bud* is distributed among the players. Let $\theta_j \in (0,1)$ be the share of player j, with $\sum_{j=1}^{m} \theta_j = 1$.
2. **A competitive market for emissions permits**, which clears at each period. Let ω_j^t be the vector of permits for country j at period t.
3. **CCS penetration**. We denote ccs_j^t the amount of emissions of country j sequestered at period t at cost C^t and $\overline{ccs}_j^t$ the upper bound for sequestration for country j at period t.

Model: Then we consider the game where each player j controls the permit allocations schedule $(\omega_j^t : t = 0, \dots, T-1)$ with $\Omega^t = \sum_{j=1}^{m} \omega_j^t$ and tries to achieve

$$\max_{\omega_j, ccs_j \leq \overline{ccs}_j} \left\{ \sum_{t=0}^{T-1} \beta_j^t(\pi_j^t(\mathbf{e}_j^t(\Omega^t)) + p^t(\Omega^t)(\omega_j^t - \mathbf{e}_j^t(\Omega^t) + \mathrm{ccs}_j^t) - C^t \mathrm{ccs}_j^t \right\},$$

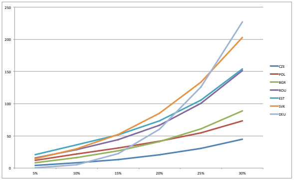
subject to actions chosen by the other players and under the budget sharing constraint

$$\sum_{t=0}^{T-1} \omega_j^t \leq \theta_j \mathrm{Bud}. \tag{1}$$

Here $\pi_j^t(e_j^t)$ represents the economic benefits obtained from emissions by country j, at time t.

Numerical implementation

- Total emissions budget on 2020-2050, Bud=99 Gt CO_2
- $-\pi_j^t(e_j^t)$ are abatement cost function estimated from 200 runs of the CGE GEMINI-E3



- $\overline{ccs}_j^t$ are based on CO_2 storage capacity and emissions from electricity generation, the CCS penetration rate is assumed to be linear between 2030 and 2050
- The cost of CCS is 110 \$/tCO_2 and half of emissions from electricity generation can be sequestered in 2050
- Discount rate, $\beta_j = 5\%$
- Allocation shares θ_j are based on the following rules:
  - Sovereignty - Allocations are proportional to emissions in 2010
  - Ability to pay - Abatements are proportional to GDP in 2010
  - Egalitarian - Allocations are proportional to population in 2010

Nash equilibrium: deterministic case

Cumulative discounted welfare losses (in % of cumulative discounted household consumption)

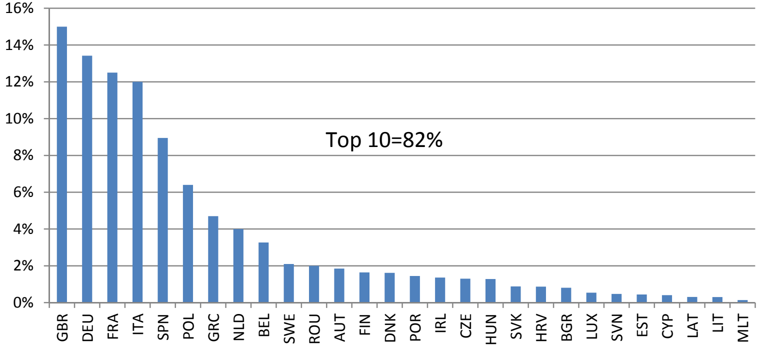
	Sovereignty	Ability	Egalitarian
Austria	0.36	2.57	0.92
Belgium	0.82	1.56	2.83
Bulgaria	-7.74	-18.17	-14.09
Cyprus	9.67	-4.91	9.67
Czech Republic	-11.29	-16.54	-4.70
Germany	-1.60	1.12	-0.18
Denmark	1.66	-1.18	2.35
Estonia	-2.16	-11.66	6.92
Finland	0.34	0.81	2.81
France	1.68	2.72	0.52
Great Britain	1.16	1.03	1.39
Greece	7.08	-8.19	7.08
Croatia	5.90	0.54	0.17
Hungary	0.42	-0.72	-3.69
Ireland	2.27	0.19	2.76
Italy	1.24	2.28	0.65
Latvia	3.78	-1.06	-2.32
Lithuania	-1.61	-1.62	-5.75
Luxembourg	5.14	-1.28	9.03
Malta	4.66	-1.07	4.66
Netherlands	-1.10	0.88	1.65
Poland	-3.59	-11.13	-1.80
Portugal	1.12	0.35	-1.87
Romania	0.02	-3.92	-10.47
Spain	1.76	0.18	0.47
Slovak Republic	-0.84	-2.98	-1.93
Slovenia	1.85	0.12	1.85
Sweden	2.27	5.00	1.08
EU-28	0.59	0.59	0.59

Nash equilibrium: deterministic case

Cumulative discounted welfare losses (in % of cumulative discounted household consumption)

	Sovereignty	Ability	Egalitarian	Fair
Austria	0.36	2.57	0.92	0.50
Belgium	0.82	1.56	2.83	0.48
Bulgaria	-7.74	-18.17	-14.09	0.60
Cyprus	9.67	-4.91	9.67	0.54
Czech Republic	-11.29	-16.54	-4.70	0.55
Germany	-1.60	1.12	-0.18	0.63
Denmark	1.66	-1.18	2.35	0.56
Estonia	-2.16	-11.66	6.92	0.55
Finland	0.34	0.81	2.81	0.59
France	1.68	2.72	0.52	0.63
Great Britain	1.16	1.03	1.39	0.61
Greece	7.08	-8.19	7.08	0.52
Croatia	5.90	0.54	0.17	0.59
Hungary	0.42	-0.72	-3.69	0.53
Ireland	2.27	0.19	2.76	0.53
Italy	1.24	2.28	0.65	0.61
Latvia	3.78	-1.06	-2.32	0.52
Lithuania	-1.61	-1.62	-5.75	0.47
Luxembourg	5.14	-1.28	9.03	0.49
Malta	4.66	-1.07	4.66	0.55
Netherlands	-1.10	0.88	1.65	0.58
Poland	-3.59	-11.13	-1.80	0.58
Portugal	1.12	0.35	-1.87	0.56
Romania	0.02	-3.92	-10.47	0.50
Spain	1.76	0.18	0.47	0.57
Slovak Republic	-0.84	-2.98	-1.93	0.47
Slovenia	1.85	0.12	1.85	0.41
Sweden	2.27	5.00	1.08	0.60
EU-28	0.59	0.59	0.59	0.59

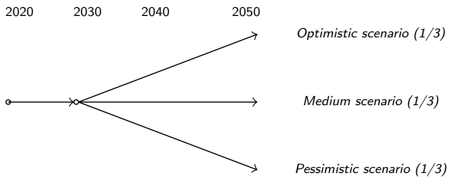
EU burden sharing in % *Fair solution*



Stochastic analysis on CCS deployment

We define three contrasted scenarios of CCS deployment

- **Optimistic**: The cost of CCS is 55 $/t CO_2$ and CCS technologies are expected to sequester all emissions from gas and coal power plants in 2050.
- **Pessimistic**: The cost of CCS is 165 $/t CO_2$ and CCS technologies are expected to sequester quarter of emissions from gas and coal power plants in 2050.
- **Medium**: Figures = deterministic case



An S-adapted non-coooperative game

The payoff of player j in an S-adapted equilibrium satisfies :

$$\max_{\omega_j} \quad \Bigg\{ \sum_{t<\bar{t}} (\beta_j^t(\pi_j^t(\mathbf{e}_j^t(\Omega^t)) + p^t(\Omega^t)(\omega_j^t - \mathbf{e}_j^t(\Omega^t)))+ \tag{2a}$$

$$\sum_{s\in S} \mathcal{P}(s) \sum_{t\geq\bar{t}} (\beta_j^t(\pi_j^t(\mathbf{e}_j^t(\Omega^t,s)) + p^t(\Omega^t,s)(\omega_j^t(s) - \mathbf{e}_j^t(\Omega^t,s) + \tag{2b}$$

$$u_j^t(\Omega^t,s)) - C_j^t(u_j^t(\Omega^t,s)))\Bigg\}, \tag{2c}$$

subject to actions chosen by the other players and under the budget sharing constraint

$$\sum_{t<\bar{t}} \omega_j^t + \sum_{t\geq\bar{t}} \omega_j^t(s) \leq \theta_j \mathrm{Bud}, \quad \forall s \in S. \tag{3}$$

and CCS capacity constraints

$$0 \leq u_j^t(\Omega^t,s) \leq e_j^t(\Omega^t,s), \quad \forall t \geq \bar{t},\ \forall s \in S. \tag{4}$$

European emissions profile

Deterministic case

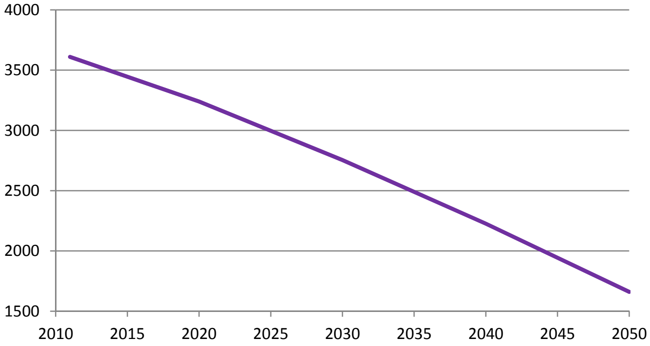


Figure: Emissions profile (in $MtCO_2$)

European emissions profile

Deterministic case *versus* without CCS

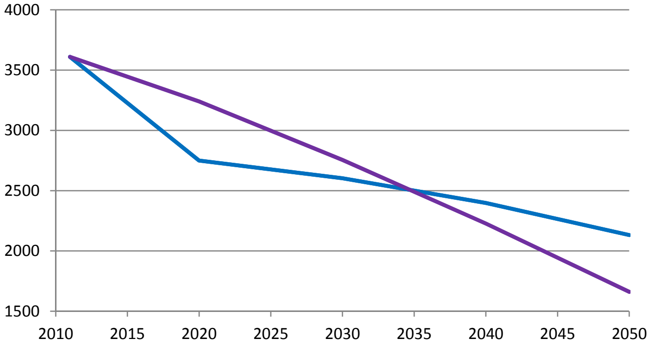


Figure: Emissions profile (in $MtCO_2$)

European emissions profile

Deterministic case *versus* stochastic case

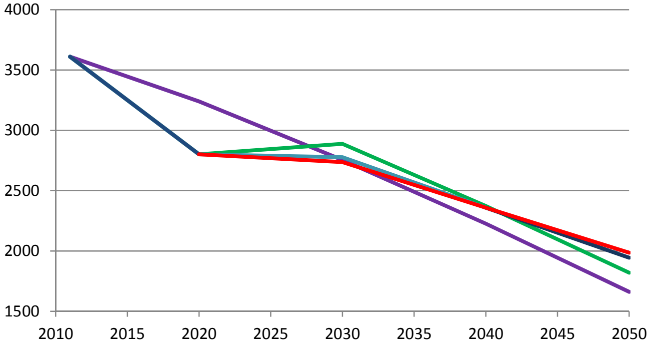


Figure: Emissions profile (in $MtCO_2$)

EU Welfare cost and CO_2 sequestered

	CO_2 price $ in 2050	Cumulative welfare loss in %	CO_2 sequestered in Gt CO_2	% of abatement
Deterministic case				
Without CCS	1103	1.2	–	–
With CCS	847	0.6	11.0	15%
Stochastic case				
Pessimistic	991	0.9	5.5	7%
Medium	761	0.6	11.1	15%
Optimistic	440	0.1	21.4	29%

Conclusion

- It is possible to design an agreement that equalizes welfare costs between the 28 EU member states
- The implementation of an EU tradable permits market is crucial as it allows to equalize marginal abatement costs
- The negotiations of the next burden sharing will become more complex and more challenging within 28 diverse Member States
- CCS deployment has a significant impact and its uncertainty has to be considered
- Postponement strategy for CO_2 abatement that we find within the deterministic scenario is no longer optimal in the stochastic case

Questions ??

Thank you for your attention ...