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ÉCOLE POLYTECHNIQUE
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A Generalized Equilibrium Approach to Balance the Residual Abatements Resulting from COP-21 Agreement

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Contents

Adressed questions

1. What do INDCs mean? And what are the economic impacts of INDC implementation?
2. How an international carbon market might affect climate agreements?
3. How to share additional efforts on 2015-2050 to reach the 2^{o}C target in 2100? How to design a fair agreement among groups of countries?
4. How each country will use its allocations on the horizon 2015-2050? What will be the associated costs for each country?

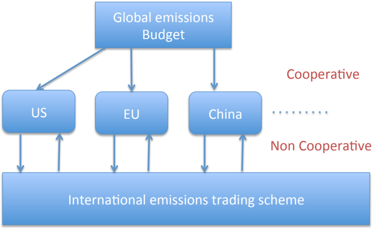
Methodology

Propose a meta-game approach for assessing burden sharing agreements for the attainment of 2050 climate target.

Methodology:

1. Identify a global emissions budget on 2015-2050 compatible with a 2^{o}C temperature increase in 2100
2. Estimate abatement cost functions for each group of countries using simulations of the Computable General Equilibrium model GEMINI-E3
3. Define a meta-game in which each country minimizes its costs according to a global share of allocations. Each country decides strategically the timing of its emissions.

Meta-games for climate negotiations



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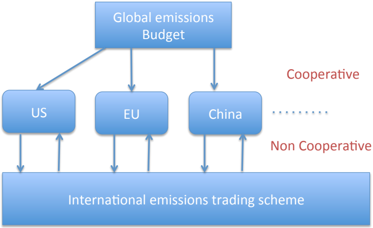

The payoff (welfare loss) of player j at equilibrium satisfies :

$$\min_{\omega_j} \left\{ \sum_{t=0}^{T-1} \beta_j^t (\pi_j^t(\mathbf{e}_j^t(\Omega^t)) - p^t(\Omega^t)(\omega_j^t - \mathbf{e}_j^t(\Omega^t))) \right\},$$

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

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

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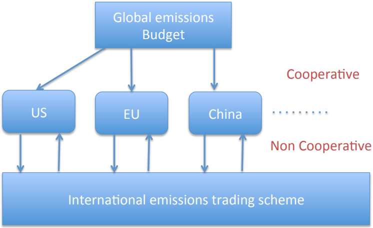

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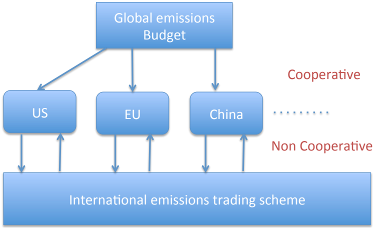
Applying standard Kuhn-Tucker multiplier method, with multipliers ν_j, we obtain the following first order necessary conditions for a Nash equilibrium:

$$\nu_j = \beta_j^t (p^t(\Omega^t) + p^{t\prime}(\Omega^t)(\omega_j^t - \mathbf{e}_j^t(\Omega^t))) \quad \forall t \forall j$$

$$0 = \nu_j(\theta_j \mathtt{Bud} - \sum_{t=0}^{T-1} \omega_j^t)$$

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

Meta-games for climate negotiations



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Abatement cost functions π are estimated through statistical emulation on a large set of GEMINI-E3 simulations

A noncooperative meta-game approach

Input Global budget *Bud* and allocations among countries (i.e., θ_j)

Model Minimize the economic impacts for each country by deciding:

1. How to use the budget on the horizon
2. Permit sales and buyings on the trading market

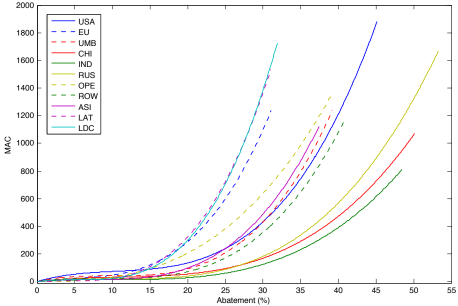
Output Emissions, Permit exchanges, Permit prices, Percentage of welfare losses, ...

$\Rightarrow$ By testing different allocations, one can find a fair burden sharing. For example if we adopt a Rawlsian approach to distributive justice, the optimal game design problem consists in finding the θ_j's in such a way that one minimizes the largest welfare loss among the countries.

Estimation of the abatement cost functions

- We use the CGE model GEMINI-E3 as a the provider of data for the estimation of the abatement cost functions for each group of countries
- Estimations are based on statistical emulations of a sample of 200 GEMINI-E3 numerical simulations (4 periods $\times 11$ = nb estimations)
- The abatement costs are polynomial functions of degree 4 in the country abatement level

$$AC_j(t) = \alpha_1^j(t)\, q_j(t) + \alpha_2^j\, q_j(t)^2 + \alpha_3^j(t)\, q_j(t)^3 + \alpha_4^j(t)\, q_j(t)^4. \quad (1)$$



INDC analysis and consolidation

Difficulties to convert INDCs in consistent emissions abatements in 2030:

- Objectives are related to different reference emissions (Historical emissions, BAU emissions, Intensity target, etc)
- Conditional and unconditional targets
- Objective year: from 2025 to 2035
- Missing information and unsubmitted INDCs

$\Rightarrow$ We use conventional target related to GEMINI-E3 BAU scenario.

INDC targets in Mt CO2-eq in 2030

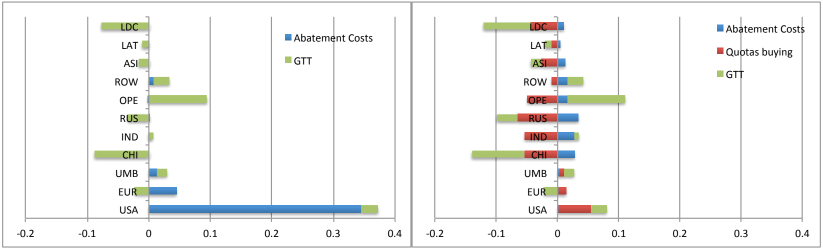
	Unconditional	Conditional	Reduction compared to GEMINI-E3 BAU
USA	4’045	3’796	-47%
EUR	3’230	3’230	-25%
UMB	2’510	2’499	-14%
CHI	17’748	15’860	0%
IND	6’681	6’482	0%
RUS	2’649	2’473	-1%
OPE	3’834	3’456	-2%
ROW	3’688	3’465	-13%
ASI	5’491	4’975	0%
LAT	4’245	4’059	0%
LDC	4’713	4’423	0%
World	58’833	54’718	

INDCs impacts on welfare losses on [2015, 2030]

	Without International carbon market			With International carbon market		
	Welfare loss in % of disc. HC	CO_2 prices in $ /t 2020	2030	Welfare loss in % of disc. HC	CO_2 prices in $ /t 2020	2030
USA	0.37	53	71	0.08	3.6	5
EUR	0.02	27	36	-0.01	3.6	5
UMB	0.03	7	10	0.03	3.6	5
CHI	-0.09	-	-	-0.11	3.6	5
IND	0.01	-	-	-0.02	3.6	5
RUS	-0.03	-	-	-0.07	3.6	5
OPE	0.10	-	-	0.06	3.6	5
ROW	0.03	2	3	0.03	3.6	5
ASI	-0.02	-	-	-0.03	3.6	5
LAT	-0.01	-	-	-0.02	3.6	5
LDC	-0.08	-	-	-0.11	3.6	5
World	0.08			0.04		

- International carbon market has a positive impact on global and all individual costs.
- Low welfare losses clearly reflect a lack of ambition of INDCs.

Decomposition of welfare losses



Emissions budget on 2015-2050

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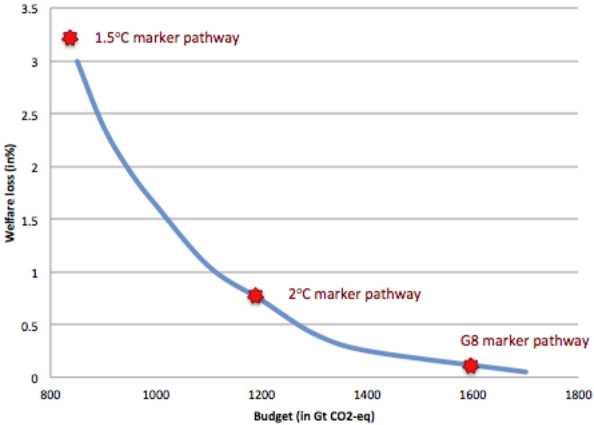
DISCUSSION BRIEF

The Three Salient Global Mitigation Pathways Assessed in Light of the IPCC Carbon Budgets

	1.5°C marker pathway	2.0°C marker pathway	G8 marker pathway
Peak year	2014	2014	2021
2020 emissions (Gt CO_2e)	38	44	58
Peak rate of decline (fossil CO_2 / all gases)	-9.0% / -7.1%	-5.5% / -3.4%	-4.5% / -4.4%
Year of peak decline rate (fossil CO_2 / all gases)	2029 / 2020	2075 / 2019	2040 / 2035
% reduction by 2050 vs. 1990 (all gases)	-80%	-49%	-42%
Budget 2000–2050 (Gt CO_2/Gt CO_2e)	995 / 1,430	1,390 / 1,850	1,635 / 2,215
Budget 2012–2050 (Gt CO_2/Gt CO_2e)	605 / 910	1,000 / 1,330	1,245 / 1,695
Budget 2000–2100 (Gt CO_2/Gt CO_2e)	1,020 / 1,720	1,660 / 2,380	1,995 / 2,860
Budget 2012–2100 (Gt CO_2/Gt CO_2e)	630 / 1,200	1,275 / 1,860	1,610 / 2,335

Table 1. Key data for the three marker pathways.

Global welfare loss on 2015-2050



Example #1 of fair agreement (2^{o}C target) on [2015, 2050]

Region	Emissions budget in Mt CO_2-eq	Welfare loss	Abatement cost	Permit buying	GTT
		in % of discounted household consumption			
USA	166852	0.7	0.5	0.1	0.2
EUR	80240	0.8	0.2	0.7	-0.2
UMB	63602	0.7	0.3	0.2	0.1
CHI	264910	0.7	2.3	-1.0	-0.7
IND	73986	0.7	1.4	-0.7	0.0
RUS	57230	0.7	1.4	-0.6	-0.2
OPE	100890	0.7	1.1	-1.2	0.9
ROW	101480	0.7	0.9	-0.3	0.2
ASI	105020	0.8	0.8	0.1	-0.2
LAT	86730	0.7	0.3	0.4	-0.1
LDC	79060	0.7	0.8	0.2	-0.3
World	1’180’000	0.8			

Example #2 of fair agreement (2^oC target) on [2015, 2050]

Region	Emissions budget in Mt CO_2-eq	Welfare loss	Abatement cost	Permit buying	GTT
		in % of discounted household consumption			
USA	153046	0.9	0.5	0.3	0.2
EUR	69620	0.9	0.2	0.9	-0.2
UMB	56640	0.9	0.3	0.5	0.1
CHI	273760	0.5	2.3	-1.2	-0.7
IND	76346	0.5	1.4	-0.9	0.0
RUS	58882	0.5	1.4	-0.9	-0.2
OPE	103250	0.5	1.1	-1.4	0.9
ROW	105020	0.5	0.9	-0.5	0.2
ASI	109150	0.5	0.8	-0.1	-0.2
LAT	90270	0.5	0.3	0.3	-0.1
LDC	84016	**0.0**	0.8	-0.5	-0.3
World	1180000	0.8			

Conclusion and Perspectives

Conclusion

- INDCs commitments are weak.
- It is possible to design fair agreements (eg, equalizing welfare costs between coalitions)
- The implementation of a tradable permits market is crucial as it allows to equalize marginal abatement costs and to reduce welfare losses

Perspectives

- Extend the model to robust optimization to take into consideration statistical errors in the calibration of abatement cost functions
- Apply meta-game on alternative economic models (eg. TIMES)