Energy Application

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Based on material developed by
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Emission reduction targets in GTAP-E

Modified version of GTAP incorporating:

- Carbon accounting
- Carbon taxation
- Emission trading
- Energy-capital substitution, inter-fuel substitution
- Cost of abatement

UNFCCC* prescribed targets under following scenarios:

notr	• No emission trading
tr	• Emissions trading between Annex 1** regions
wtr	• Emissions trading between all the regions

* UNFCCC: United Nations Framework Convention on Climate Change

** Annex 1 Regions: Countries which have agreed to reduce carbon emissions during UNFCCC 2011 convention, aggregated into regions for analysis in GTAP

Marginal costs of achieving the emission reduction targets

	notr		tr		wtr	
	% reduction in emissions	2004 USD per tonne of carbon	% reduction in emissions	2004 USD per tonne of carbon	% reduction in emissions	2004 USD per tonne of carbon
USA	-17.0	67.7	-15.7	59.6	-7.0	22.2
EU	-17.0	90.0	-12.4	59.7	-5.2	22.2
EEFSU	1.6	0.0	-21.0	59.1	-9.5	22.2
Jpn	-30.0	248.2	-11.3	59.7	-4.5	22.2
China	0.4	0.0	0.3	0.0	-16.6	22.2
India	0.7	0.0	0.5	0.0	-15.8	22.2

No trading means unit cost of abatement = average cost in each region

With Annex 1 trade allowed unit cost of abatement decreases because regions act based on marginal abatement cost curve

Further reductions in abatement cost when additional participants to the emission market added

Macroeconomic effects of implementing the emission targets

In percentage changes	notr		tr		wtr	
	Welfare	TOT	Welfare	TOT	Welfare	TOT
USA	-0.10	0.49	-0.10	0.40	-0.05	0.18
EU	-0.12	0.17	-0.08	0.13	-0.01	0.07
EEFSU	-0.94	-1.11	1.08	-0.21	0.09	-0.33
Jpn	-0.41	0.90	-0.14	0.39	-0.03	0.26
China	0.01	0.07	0.01	0.07	0.22	0.13
India	0.25	0.54	0.18	0.39	0.16	0.55

India gains by replacing Annex 1 production ['leakage']

EEFSU does well from sale of hot air*

China gains from comparative advantage in emissions market

* Hot air: quota in excess of unconstrained emissions, available for sale by member of trading bloc

Potential uses of the model

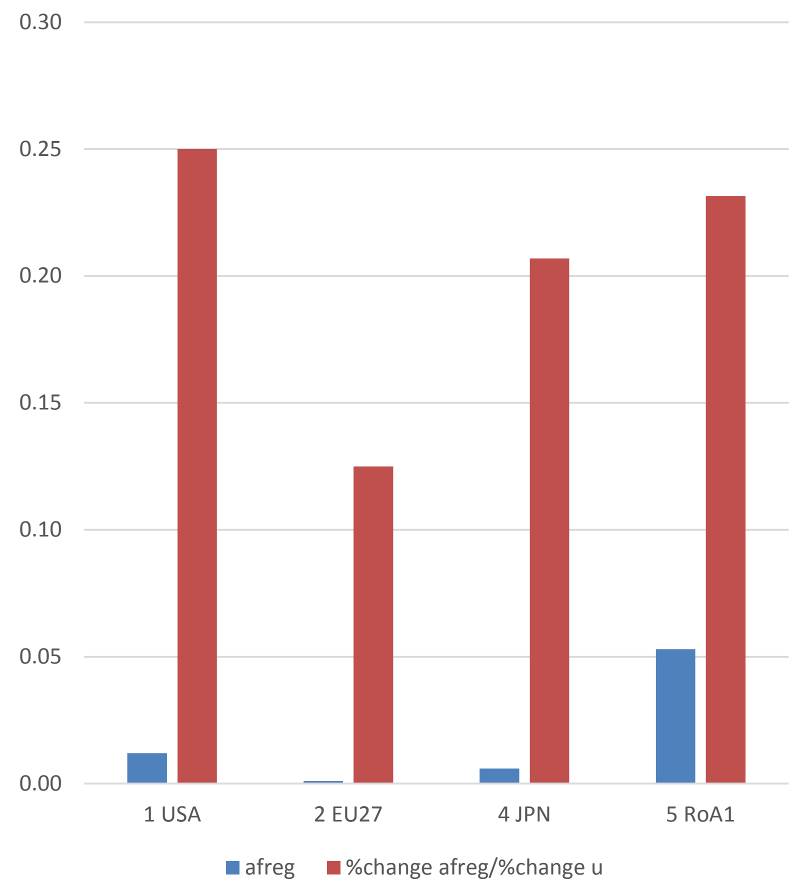
- Investigate potential avenues for ‘politically’ viable second-best options
- Test the impacts of a Pigouvian carbon tax
- Explore the impact of technological change
  - Input augmentation
  - Capital augmentation
- Comparing carbon taxes to other policy mechanisms

No Annex 1 Losers

Pralabh Bhargava
Erin Sherry

No Annex 1 Losers

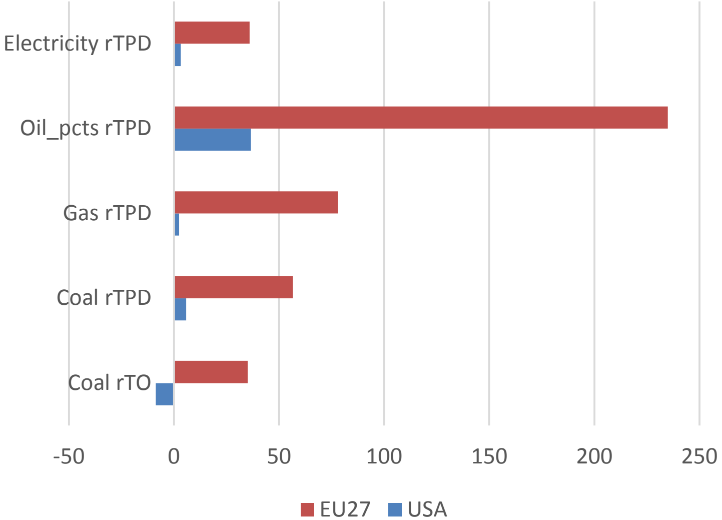
% change in per capita utility		
	wtr	no A1 losers
1 USA	-0.05	-
2 EU27	-0.01	-
3 EEFSU	0.09	0.09
4 JPN	-0.03	-
5 RoA1	-0.23	-
6 EEx	-0.37	-0.37
7 CHN	0.22	0.22
8 IND	0.16	0.17
9 ROW	0.05	0.05



Why does the USA need more efficiency gains per unit change in utility?

Where does additional welfare come from?

	Co2trd	Alloc_A1	Tech_C1	Tot_E1	IS_F1	Total
USA	-14	307	4813	51	-37	5,119
	-0.3%	6.0%	94.0%	1.0%	-0.7%	
EU27	-5	129	667	67	3	861
	-0.6%	15.0%	77.5%	7.8%	0.3%	



Domestic tax welfare impact $m				
	Firm		Private	
	USA	EU	USA	EU
Gas	-2	26	1	38
Oil_pcts	42	-2	36	1
Electricity	1	0	2	5
En_Int_ind	0	0	7	47
Oth_ind_ser	3	21	69	91
Sum of above	*44*	*45*	*115*	*182*

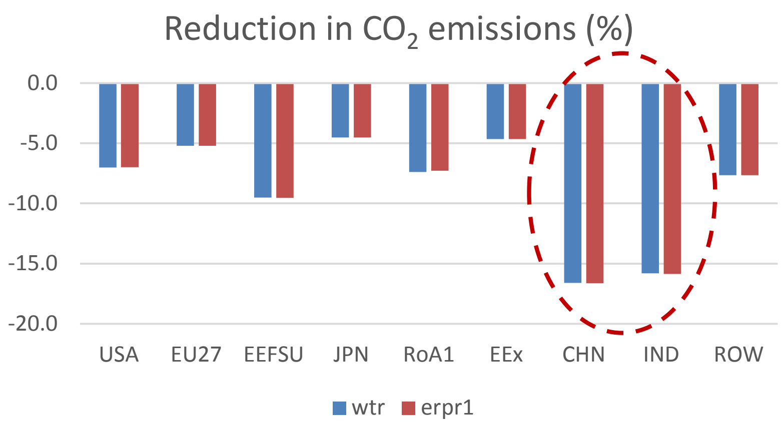
Exogenous to avoid any negative per capita utility change

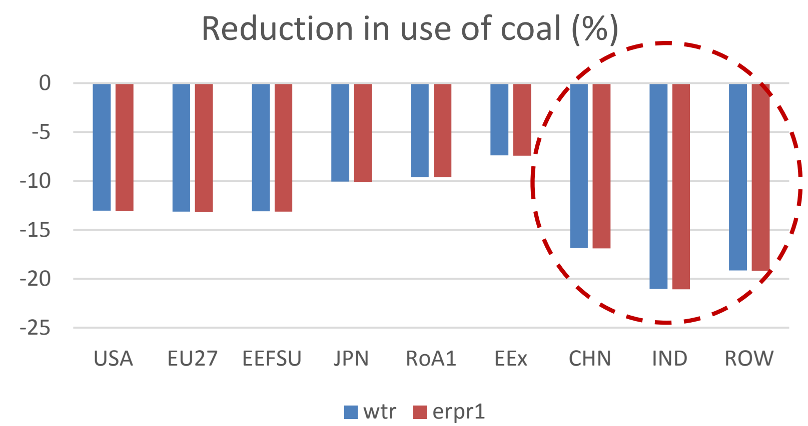
Who does lose?

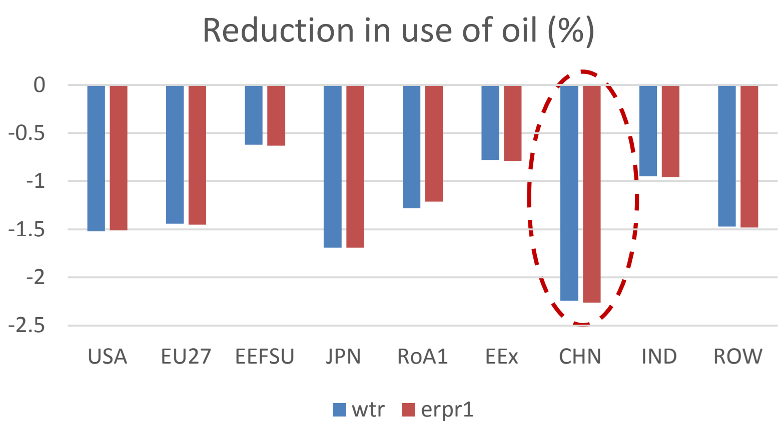
Total welfare change by region			
	wtr	No A1 losers	Difference
1 USA	-5,119	0	5,119
2 EU27	-861	0	861
3 EEFSU	728	706	-22
4 JPN	-1,153	0	1,153
5 RoA1	-4,762	0	4,762
6 EEx	-9,237	-9,271	-34
7 CHN	3,314	3,353	39
8 IND	955	968	13
9 ROW	1,644	1,670	26
Total	-14,490	-2,573	11,917

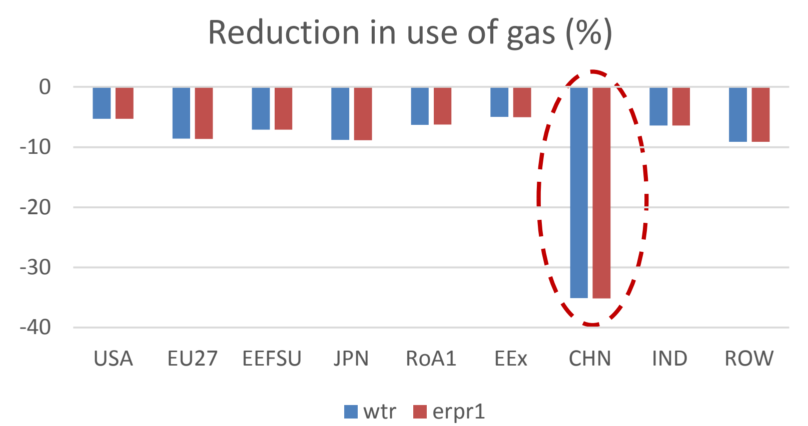
- EEFSU and EEx slightly worse off
- China, India and RoW slightly better off
- Very small increase in the carbon tax rate (22.2 to 22.3 $/ton)
- No leakage impacts

What about the carbon footprint?









Regional Carbon Tax

Hawley Campbell

Silvia Palma Rojas

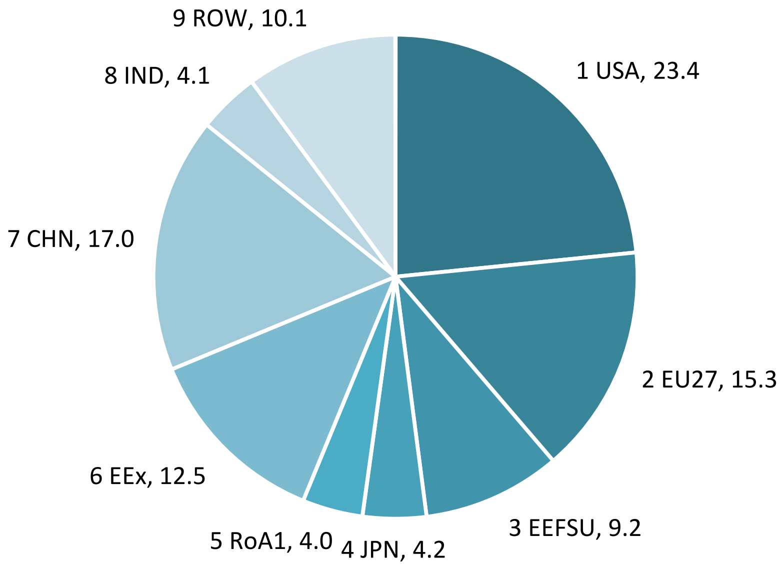
Regional Carbon Tax: Motivation

- Concern for global carbon emissions.
- Interest in global policy mechanism.
- Pilot assessment of regional carbon tax.
- US and EU are big players in the global climate change debate and are interested in using economic instruments in climate change policies.

Research Question:

How does a regional carbon tax on the US and EU bloc affect the competitiveness of energy products in these countries?

Global Share of Carbon Emissions (%)



Experiment

1. Created new bloc → USAEU
2. Determined carbon price for an 11% reduction target = \$42/tonne CO_2.
3. Introduced carbon tax to USAEU bloc only, all other regions unconstrained.

   - Blocs: USAEU, EEFSU, JPN, RoA1, Eex, CHN, IND, ROW.

Taxed products: coal, gas, oil, oil products

Results – Domestic

Percentage change in domestic output and demand (%)

	US		EU	
	Output	*Demand*	*Output*	*Demand*
Agriculture	-0.17	-0.10	-0.17	-0.13
Coal	-20.29	-21.91	-20.68	-21.85
Oil	-1.44	-1.46	-0.87	-0.81
Gas	-8.63	-9.36	-9.42	-21.10
Oil_pcts	-3.90	-4.02	-1.48	-1.38
Electricity	-4.84	-4.75	-2.68	-2.42
En_Int_ind	-1.11	-0.75	-0.69	-0.43
Oth_ind_s		[illegible]		[illegible]

Percentage change in supply price (%)

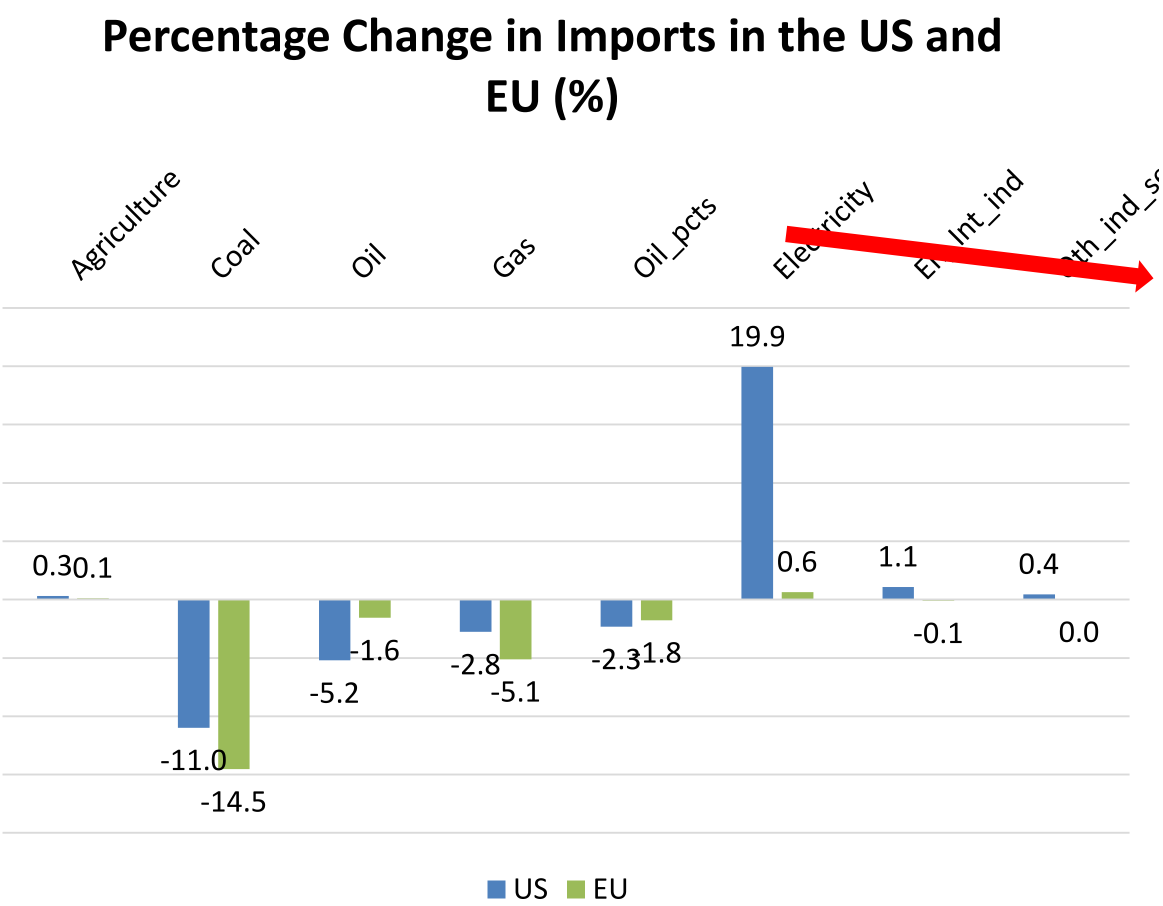
	USA	*EU*
Agriculture	0.3182	0.3269
Coal	-2.0865	-1.8646
Oil	-1.5124	-0.9009
Gas	-1.5001	-1.7271
Oil_pcts	0.0564	-0.2857
Electricity	8.8035	4.3525
En_Int_ind	0.8536	0.5695
Oth_ind_ser	0.344	0.2075
CGDS	0.3209	0.2044

Results – Exports

Range in percentage change in exports from the US and EU to all other regions.

	US		*EU*	
	Min	Max	Min	Max
Coal	-7.5	13.5	-8.1	12.3
Oil	2.5	9.5	-4.4	2.7
Gas	21.5	54.7	31.0	66.8
Oil_pcts	-4.5	-1.3	-3.2	0.1

Results – Imports



Input price change in US electricity sector (%)

	Electricity
Agriculture	0.2663
Coal	66.7004
Oil	13.5744
Gas	11.6264
Oil_pcts	1.4574
Electricity	8.7707
En_Int_ind	0.7181
Oth_ind_ser	0.3322

Results – Leakage

Global emissions (MtCO2)		
	Baseline	*Policy*
USA	1649.13	1446.95
EU27	1079.24	971.31
EEFSU	649.47	653.17
JPN	298.81	300.22
RoA1	284.41	286.77
EEx	883.17	887.41
CHN	1199.74	1201.06
IND	288.75	289.27
ROW	712.27	715.90
Total CO2 increase 17.18		
Total CO2 decrease -310.11		
Leakage rate 5.5%	**Global reduction** 94.5%	

Results – Macroeconomics

Percentage change (%) per region		
	USA	EU
GDP	-0.09	-0.08

Change in EV (millions of USD)					
	co2trd	*alloc_A1*	*tot_E1*	*IS_F1*	*Total*
USA	-0.02	-10449.86	3236.10	417.53	-6796.24
EU	-0.02	-10311.29	2970.17	-130.41	-7471.54

Conclusions

Research Question:

How does a regional carbon tax on the US and EU bloc affect the competitiveness of energy products in these countries?

- The products remained competitive on the global market.
- The tax was effective at reducing carbon emissions in the USAEU without causing significant leakage worldwide.
- There was no significant change GDP in the US and EU, but some loss in welfare.

Increasing Technological Change

Heleen Bartelings

Rebecca Ewing

Increasing Technological Change

- **Intro**
  - **increasing energy efficiency**
  - **lowering emissions through technology options**
  - **Assuming tax constant**

- **set up experiment**
  - **what shock**
    - **10% to afall(capital,electricity,EU27)**
    - **10% to afall(capital,electricity,Jpn)**
  - **what base**
    - **Emissions reduced by govt policy – no trade in emissions**
    - **So tech change is being applied on top of a carbon reduction policy**
    - **Applied in single region only**
  - **what closure?**
    - **2 closures examined for EU and Japan**
    - **Consider the fixed tax easier to interpret**

- **Result for EU**
  - **Surprise – emissions go up!**
  - **Show numbers**
    - **With tax fixed, emissions for all sectors rose by ~0.4%**
  - **Why?**
    - **Hypothesize “rebound effect”**
    - **Where increase in use of electricity can lead to increase in emissions**

- **More in depth examination of results**
  - **Tech shock makes electricity cheaper (price falls by 3%)**
  - **Increased Demand for electricity**
  - **Electricity production up (2.8%)**
    - **Higher per unit capital input - price of capital in EU rises (0.2%)**
    - **Lower per unit energy input**
      - **Might expect energy cons to go down, but in total it goes up (coal use up by 0.73%)**
      - **Opposing forces**
      - **Increased energy efficiency of electricity vs increased overall production**
    - **Emissions from electricity sector increase due to expansion effect (2%)**

- However, the expansion effect is not the only source of the increase in emissions.
- Unexpectedly we also have expansion in coal sector.
- What is happening with Coal?
  - Coal supply price is down (0.3%)
  - Electricity is input to coal production (about 10% of total factor costs).
  - We followed the impact of electricity price decrease in coal production sector, found that it is responsibly for 86% of the decrease in coal price
  - Increased demand for coal
  - Increased production coal
  - Increased emissions from sectors using coal as input.

- Japan
  - Same experiment, but emissions went down
  - Emissions declined by 0.1%
  - Electricity price down by 3.8%
  - Electricity production up similar to EU ~3%
  - As in EU coal use by electricity up by 0.5%
  - Emissions from electricity sector increase due to expansion effect (x%)
  - Unlike EU, overall emissions go down

- Coal story is different in Japan
  - All coal imported, so no electricity price effect like we saw in EU from feed-through of electricity price increase.
  - Japan is a relatively small importer on world markets, so no world price effects
  - Domestic coal price increases slightly (0.08%), due to increased demand by electricity sector
  - No increased use of coal by other sectors In Japan.
  - Other oil products is other user of coal, use declines, leading to lower emissions. This effect overshadows expansion effect from electricity, leading to decline in emissions overall.

Green technological change and carbon leakage

Octavio Fernandez-Amador

Doris Oberdabernig

Green technological change and carbon leakage

Octavio Fernandez-Amador
Doris Oberdabernig

- Reduction quotas and Emission Trading Systems (ETSs) are not enough to abate CO2e
- Green technological progress will be needed to make compatible emissions reduction and economic growth
- Our question: What are the effects of ETSs on the process of green technological development?

Experiment

- We extend the experiment on introduction of ETSs by adding a green technology shock in USA

- 3 scenarios: Imposition of quotas under no ETS, under ETS restricted to Annex I countries (and under worldwide ETS)

- We proxy *green technological progress* using shifting factor augmenting technology in the Energy sectors

- We introduce a 10% factor augmenting tech. shock in Energy sectors to all traded commodities in the USA

Hypothesis

- Green technology progress may free certificates and promote emissions trading
- Price of emissions certificates may decrease and other countries benefit from a country specific technology shock
- “Hot air” countries may not benefit from shock
- Since quantities are restricted by the system of quotas, price effect may dominate
- The effect of the green technology shock on the country level may not depend on ETS (from functional form)
- However, there may be price “spillovers” from trade pressures

Scenario 1: No emissions trade

	%change in emissions		RCTAX		%change in utility		
	Baseline	Difference	Baseline	Difference	Baseline	Tech. shock	Difference
1 USA	-17.0%	0.0%	67.7	-5.7	-0.10	0.75	0.85
2 EU27	-17.0%	0.0%	90.0	1.1	-0.12	-0.10	0.02
3 EEFSU	1.6%	0.1%	0.0	0.0	-0.94	-1.11	-0.17
4 JPN	-30.0%	0.0%	248.2	2.5	-0.41	-0.40	0.01
5 RoA1	-40.0%	0.0%	276.0	0.9	-1.06	-1.06	0.00
6 EEx	1.6%	0.1%	0.0	0.0	-0.61	-0.74	-0.13
7 CHN	0.4%	0.0%	0.0	0.0	0.01	0.04	0.03
8 IND	0.7%	0.0%	0.0	0.0	0.25	0.32	0.07
9 ROW	1.5%	0.2%	0.0	0.0	0.11	0.12	0.01
Total	-8.9%	0.0%					

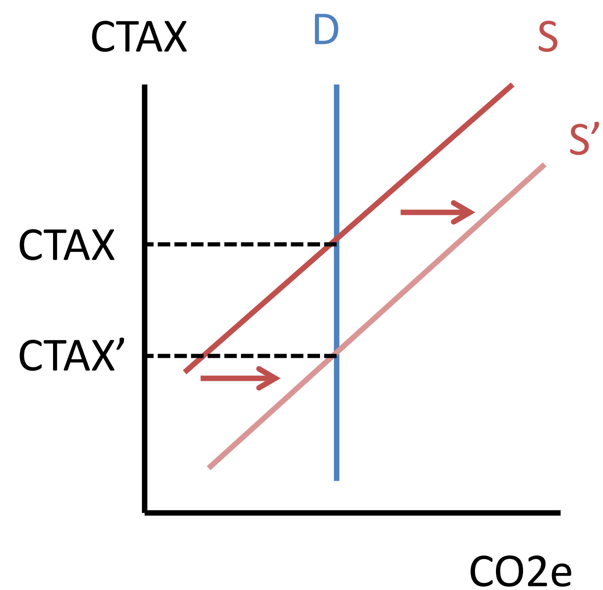
leakage (incl. EEFSU in constrained)	4.93	0.32

Baseline scenario: Emission quotas without technical change
Difference to emissions quotas with afall(EGY_COMM,PROD_COMM,"USA") = uniform 10

Scenario 1: No emissions trade

US supply of CO2 emissions at the world market

- af ↑
- p (egy_comm) ↓
- Output is (indirectly) restricted by emissions quota
- CO2/GDP↓
- Supply of CO2 permits ↑
- Demand for permits is inelastic (no emissions scenario)

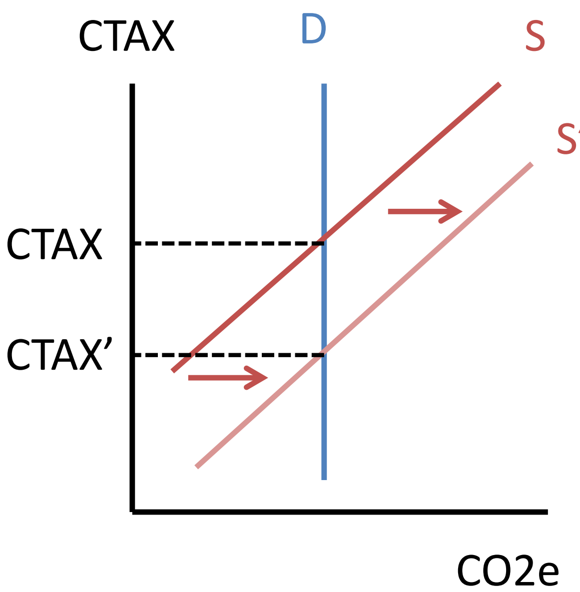


- CO2 traded quantity is unaffected
- Abatement cost ↓

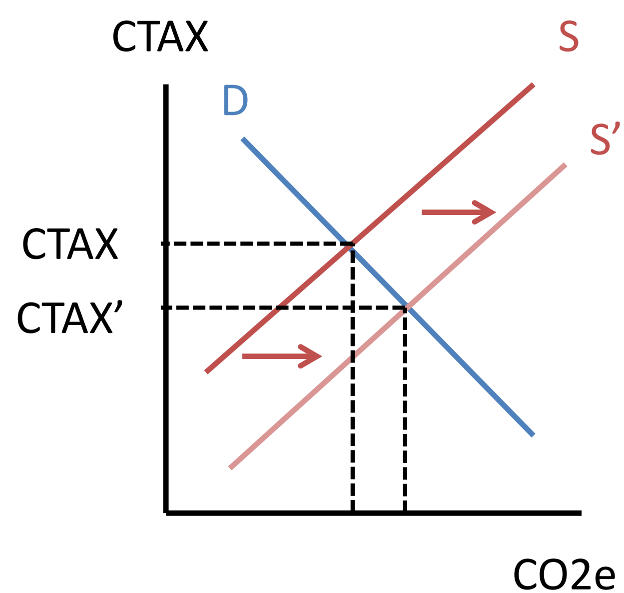
Scenario 2: Emissions trade among Annex 1 countries

US supply of CO2 emissions at the world market

No emissions trade scenario



Emissions trading scenario



Scenario 2: Emissions trade among Annex 1 countries

	%change in emissions		RCTAX		%change in utility		
	Baseline	Difference	Baseline	Difference	Baseline	Tech. shock	Difference
1 USA	-15.7%	-0.7%	59.6	-2.1	-0.10	0.74	0.84
2 EU27	-12.4%	0.5%	59.7	-2.0	-0.08	-0.05	0.03
3 EEFSU	-21.0%	0.5%	59.1	-1.9	1.08	0.85	-0.23
4 JPN	-11.3%	0.6%	59.7	-2.0	-0.13	-0.11	0.02
5 RoA1	-16.2%	0.5%	59.8	-2.0	-0.50	-0.49	0.01
6 EEx	1.3%	0.1%	0.0	0.0	-0.43	-0.56	-0.13
7 CHN	0.3%	-0.1%	0.0	0.0	0.01	0.05	0.04
8 IND	0.5%	0.0%	0.0	0.0	0.18	0.24	0.06
9 ROW	1.2%	0.2%	0.0	0.0	0.08	0.10	0.02
Total	-8.3%	0.0%					

leakage (incl. EEFSU in constrained)	4.12	0.18

Baseline scenario: Emission quotas without technical change
Difference to emissions quotas with afall(EGY_COMM,PROD_COMM,"USA") = uniform 10

Scenario 2: Emissions trade among Annex 1 countries

- Green technology attenuates reduction in CO2 emissions
  - Price of CO2 certificates decrease at the world market (RCTAX ↓)
  - ↑ production => Demand for permits from other countries ↑
- Utility increase wrt. baseline in all countries but EEFSU and EEx
  - US: af ↑, decrease in CO2 needs in US, closer to free market solution, quota is less distortionary and u ↑
  - Other countries: increase in US demand for imports, decrease in abatement costs => u ↑
  - EEFSU: hot air region => decrease in RCTAX reduces utility
  - EEx: net energy exporters => falling import demand by other countries

Alternative Policy Instruments for Carbon Emission Abatement : Gas Subsides vs Taxation

Katarzyna (Kasia) Zawalinska
Daisy Nguyen

Theoretical and policy considerations for **subsidies**

- **Subsidies** may in theory be more favourable than carbon taxes, if we aim to achieve the similar emission reduction by subsidizing less carbon intensive energy as gas . For example India is currently subsidizing gas for households. But we can also imagine policy subsidizing gas for firms using gas as an input.

- **Research question**: can subsidy for gas be better than the carbon tax, if so how? More efficient emission reduction? Better welfare effect? Positive GDP effect?

- **Expectations**: Firms and Households will substitute gas for other types of energy, especially coal so the reduction in emissions can be achieved

*Experiment design for **subsidies***

- We base on world trade scenario (**wrt**) but policy is implemented only in USA (but other regions are involved in trade)
- Subsidising the most environmentally friendly energy (i.e. **gas**) both **domestic** and **imported** used by both **firms** and **households**
- **1 base line and 4 policy scenarios** were analysed

Scenario name	Scenario description	Closure	Shock
BASE	**carbon tax** on USA of 22.2 USD pre tonne of carbon	As in original paper	**Shock RCTAXB("world") = 22.2;**
SUBSFirmDom	subsidy on **domestic gas** purchased by **firms in USA**	Closure changed: Emission endogenous	**Shock tfd("Gas",PROD_COMM,"USA") = uniform -10;**
SUBSFirmImp	subsidy on **imported gas** purchased by **firms in USA**	Closure changed: Emission endogenous	**Shock tfm("Gas",PROD_COMM,"USA") = uniform -10;**
SUBSPrivDom	subsidy on **domestic gas** purchased by **households in USA**	Closure changed: Emission endogenous	**Shock tpd("Gas","USA") = -10;**
SUBSPrivImp	subsidy on **imported gas** purchased by **households in USA**	Closure changed: Emission endogenous	**Shock tpm("Gas","USA") = -10;**

Where **shock variables** are:

-RCTAX(r) *# real carbon tax rate (1997 USD per tonne of carbon) in USA*

-tfd - *subsidy on domestic gas purchased by all industries in USA* **-tpd -** *comm.-, source-spec. shift in tax on private cons. of dom.*

-tfm - *subsidy for imported gas purchased by all industries in USA* **-tpm**(*comm.-, source-spec.*

Result in terms of emission quantity (co2t), welfare (u), GDP (vgdp)

	BASE	SUBSFirmDom	SUBSFirmImp	SUBSPrivDom	SUBSPrivImp
carbon dioxide emissions (gco2t)	-7	1.2	0.236	0.45	-0.0008
wlfare (u)	0.024	0.013	-0.026	-0.002	-0.000703
Economic growth (vgdp)	0.6	0.04	-0.1	-0.03	-0.002464

- Only Subsidies for Private consumption on imported gas was somewhat diminishing the emissions but to very little extend and with negative welfare and economic effects

1st insight into Explanation

Equation INDDOM
industry j demands for domestic good i (32)
(all,i,TRAD_COMM)(all,j,PROD_COMM)(al
G)
qfd(i,j,s) = **qft**(i,j,s) - ESUBD(i) * [pfd(i,j,s
pft(i,j,s)];

Figure1: Gas demanded by all sectors

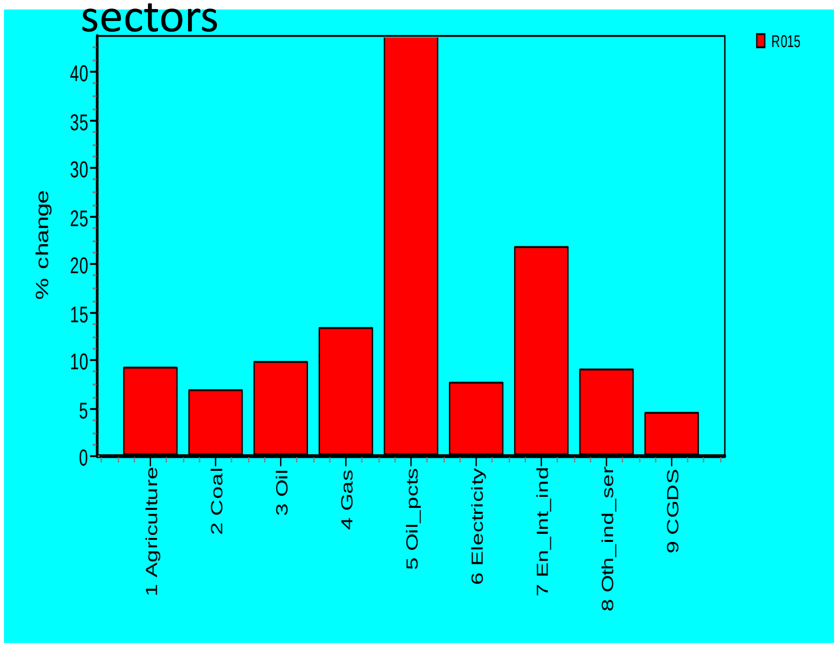
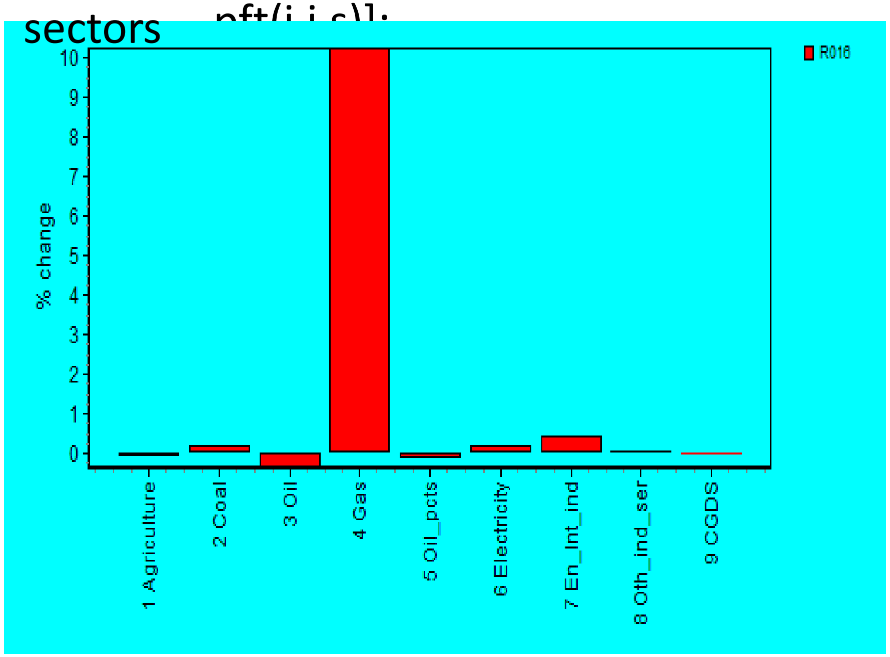


Figure2: Coal demanded by all sectors



Subsidy for gas caused an increase **in demand for gas** but **also for coal** and Oil_pct. Since the emission increased there must be only small substitution effect then (although we expected the large substitution).

2nd insight to explanation

- The **substitution between coal and gas was smaller** than we expected
- It occurred that substitution elasticity between non-coal and coal energy is rather small → GTAP-E paremeter *ELFNELY* =0.5

```
                              electricity  non-electr. energy
                                                 /\
Non-electricity energy nest                     /  \
CES (subst. el. ELFNELY)  ---------------->    /    \
                                              /      \
                                             /        \
                                      non-coal energy   coal
                                            /\
Non-coal energy nest     ------------>     /  \
CES (subst. el. ELFNCOAL)                 /    \
                                         /      \
                                        /        \
                                       /          \
                            crude oil, gas, petr. products
```

SSA analysis w.r.t. parameter was carried for *ELFNEL* as it is a critical parameter driving results.

- Ordinary change: 0.5, triangular distribution; Model solved for USA only, Straud solve the model 18 times
- Results of SSA: 89% confidence

Conclusions on subsidies

- Unexpected results:
  - subsidies for gas actually **increase the Co2 emission in USA**!
  - they make the gas cheaper but this causes **higher use of gas and expansion of gas-related industries, including coal industry so CO2 emission increased**
  - Expansion effect > substitution effect - **not much substitution of gas for coal** was observed contrary to what we expected
  - **SSA analysis w.r.t**. parameter responsible for substitution between coal and gas shows that **sometimes the coal can actually decline due to substitution effect, and hence emissions could also go down.**
  - Because the results are heavily dependent on this **substitution parameter (*ELFNELY),* it could be more explored for GTAP-E in further studies.**

Taxation choice: Case of the US

Option 1

Tax on Carbon Emission

20$ per ton carbon emission

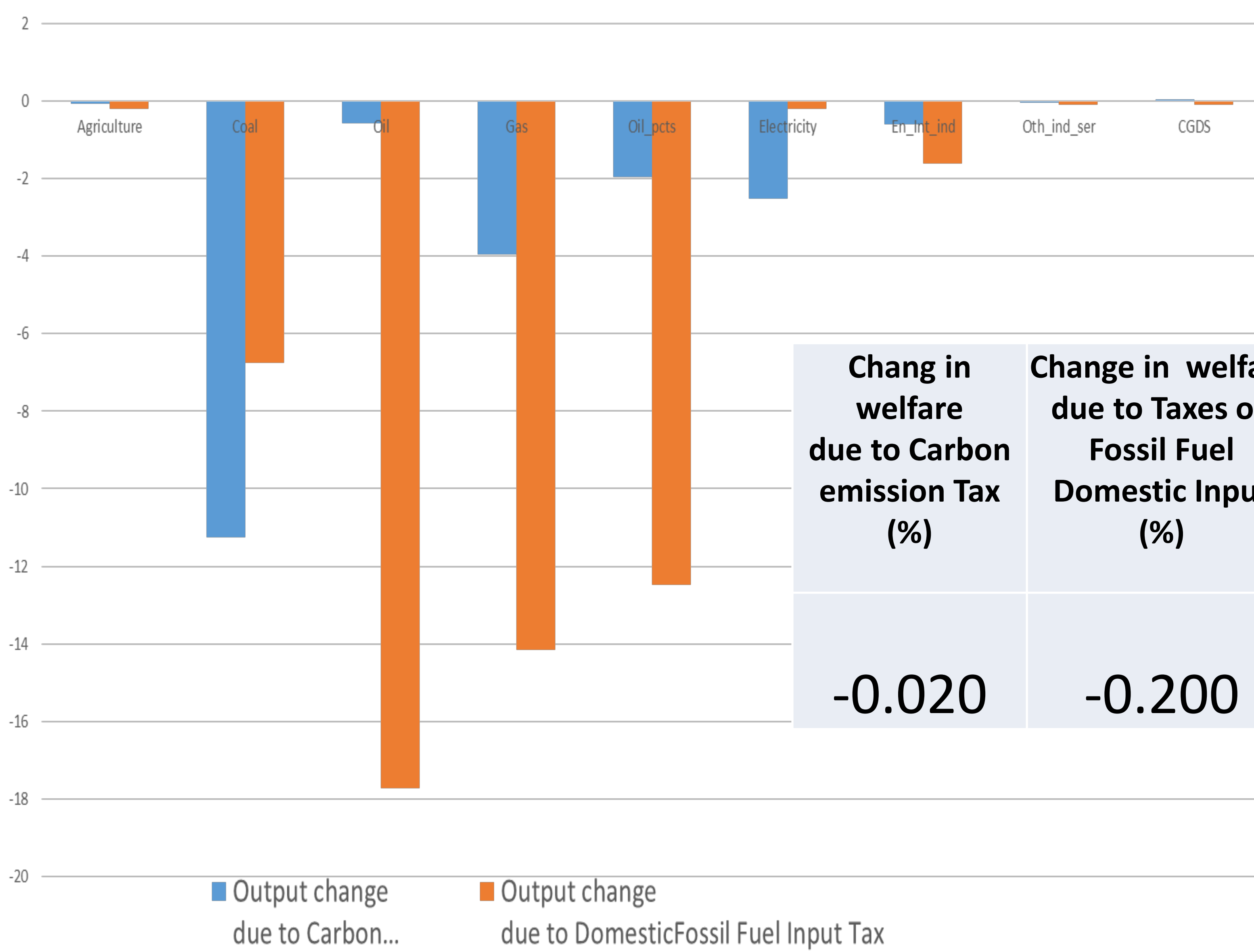
Target emission reduction : 6.64 %

Option 2

Tax on Domestic Fossil Fuel Inputs

Option 2:
Tax on Domestic Inputs subject to Carbon Emission

Reduction in Output by Industry due to Taxes



Chang in welfare due to Carbon emission Tax (%)	Change in welfare due to Taxes on Fossil Fuel Domestic Input (%)
-0.020	-0.200

Welfare changes due to Domestic Fossil Fuel Input Tax (in Millions $)

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1 Agriculture	2	0	0	0	0	0	0	0	0
2 Coal	0	0	0	-1	-94	**-127**	-7	-5	0
3 Oil	0	0	0	0	**-1190**	0	0	0	0
4 Gas	0	0	0	**-125**	**-393**	**-475**	**-668**	**-399**	0
5 Oil_pcts	**-297**	0	0	0	**-430**	**-221**	**-2816**	**-9695**	0
6 Electricity	0	-3	-5	-5	-16	18	-5	102	0
7 En_Int_ind	5	0	0	0	0	0	0	0	0
8 Oth_ind_ser	9	0	0	0	0	0	0	0	-1
Total	-281	-3	-5	-132	-2122	-805	-3496	-9997	-1

1	Agriculture
2	Coal
3	Oil
4	Gas
5	Oil_pcts
6	Electricity
7	En_Int_ind
8	Other industries
9	CGDS

Thank you for your attention