GTAP-E Small Group Presentations

Teams:
Yoji Kunimitsu & Geraldo Martha
Admir Betarelli & Aline Magalhaes
Alex Hilsop & Oh Sang Kwan
Dave Gustafson & Hao Luan

GTAP-E

- **Includes greater energy sector detail**
- **Tracks CO_2 emissions from combustion of fossil fuels, by region, source, and sector**
- **Explicit treatment of carbon taxation, emission quotas, and emissions trading**
  - **Every region is mapped to a bloc**
  - **A region that does not participate in emission trading is mapped to its own bloc**
  - **Carbon trading scenarios are modeled using combinations of Closures and Shocks**

Baseline Application of GTAP-E

- "Annex I" countries have region-specific carbon reduction targets
  - US: -17%
  - EU27: -17%
  - Japan: -30%
  - EEFSU: +9% (artifact)
  - Rest of Annex 1: -40%
- Other regions: China, India, EEX, ROW
- Three trading scenarios (see next slide)

Trading Scenario Results

A. No emissions trading ("notr")

B. Emission trading within Annex I ("tr")

C. Worldwide emission trading ("wtr")

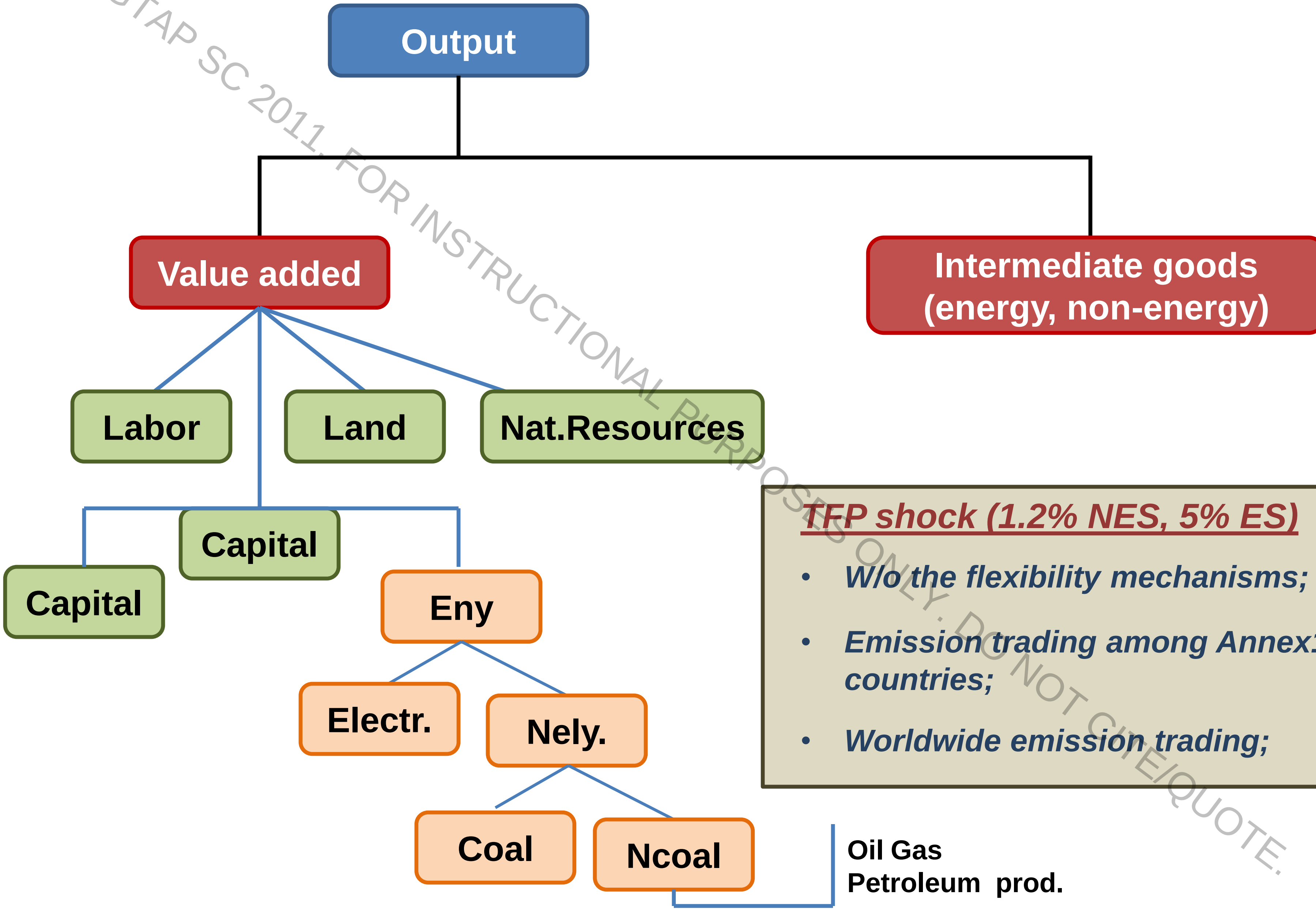
	Case A. ("notr")		Case B. ("tr")		Case C. ("wtr")	
	C emissions (%)	C price ($/tonne)	C emissions (%)	C price ($/tonne)	C emissions (%)	C price ($/tonne)
USA	-17	67.74	-15.69	59.64	-7.02	22.23
EU27	-17	90.04	-12.39	59.71	-5.22	22.23
EEFSU	1.56	0	-20.99	59.07	-9.52	22.18
JPN	-30	248.21	-11.32	59.75	-4.52	22.23
RoA1	-40	275.96	-16.22	59.85	-7.39	22.26
EEX	1.63	0	1.28	0	-4.65	22.23
CHN	0.42	0	0.26	0	-16.6	22.19
IND	0.74	0	0.5	0	-15.82	22.18
ROW	1.53	0	1.19	0	-7.64	22.22

Percent Changes in Household Utility and Terms-of-Trade

	Case A. ("notr")		Case B. ("tr")		Case C. ("wtr")	
	Utility	TOT	Utility	TOT	Utility	TOT
USA	-0.1	0.49	-0.1	0.4	-0.05	0.18
EU27	-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	0.9	-0.13	0.39	-0.03	0.26
RoA1	-1.06	-0.15	-0.5	-0.37	-0.23	-0.22
EEx	-0.61	-1.49	-0.43	-1.06	-0.37	-0.7
CHN	0.01	0.07	0.01	0.07	0.22	0.13
IND	0.25	0.54	0.18	0.39	0.16	0.55
ROW	0.11	0.12	0.08	0.1	0.05	0.14
EV (M USD)	(80,589.52)		(34,537.86)		(14,489.86)	

GTAP-E model: shock to the TFP

GTAP-E: Production Structure



TFP shock (1.2% NES, 5% ES)

- *W/o the flexibility mechanisms;*
- *Emission trading among Annex1 countries;*
- *Worldwide emission trading;*

Reduction in emissions and cost of reduction in response to TFP shock non-energy sectors

	Emissions (million t C)	% change (basel.)	% change (TFP, NES)	USD/t C (basel.)	USD/t C (TFP, NES)
Annex-1	3961,1				
no trading		-16,6	-16,5	91,2	98,6
trading (A1)		-15,4	-15,4	59,6	63,3
trading (Wld.)		-6,8	-6,7	22,2	24,5
Non-Annex-1	3083,9				
no trading		1,1	1,8	0,0	0,0
trading (A1)		0,8	1,5	0,0	0,0
trading (Wld.)		-11,0	-11,1	22,2	24,4
World	7045,0				
no trading		-8,9	-8,5	91,2	98,6
trading (A1)		-8,3	-8,0	59,6	63,3
trading (Wld.)		-8,6	-8,6	22,2	24,5

Welfare gains in response to TFP shock to non-energy sectors

	Total (basel.) USD million	Regions % chg.	Total (TFP) USD million	Regions % chg.
No trading	-80589	-1.06 to 0.25	733292	0.25 to 4.5
Trading A1	-34538	-0.5 to 1.08	781302	1.08 to 3.24
Wld.Trading	-14490	-0.37 to 1.57	802222	0.22 to 2.94

Welfare gains in response to TFP shock to non-energy sector

	No trading		Trading A1		Wld. Trading	
Region	(basel.)	(TFPs.)	(basel.)	(TFPs.)	(basel.)	(TFPs.)
1 USA	13	29	32	27	35	27
2 EU27	18	35	27	34	6	34
3 EEFSU	9	1	-24	3	-5	2
4 JPN	20	10	15	11	8	11
5 RoA1	27	3	30	5	33	5
6 EEx	19	5	31	5	64	5
7 CHN	0	6	-1	5	-23	6
8 IND	-2	1	-3	1	-7	1
9 ROW	-4	10	-7	9	-11	9

TFP shock in Electricity sector

- Assuming that
  - TFP in electricity sector increased by 5%
- Why electricity?
  - Cleaner than others
  - All people concern about it
  - It can affect to firms as well as consumers

- Then we re-simulated the carbon tax and carbon emission trade
  - Non-Trade (CO2 tax only)
  - Trade within Annex countries
  - World trade

Results about CO2 emissions and price

`		Annex I emissions reduction with no use of flexibility		Emissions reduction with trading among Annex I		Emissions reduction with worldwide emissions trading	
		gco2t	RCTAX	gco2t	RCTAX	gco2t	RCTAX
Without TFP increase in electricity sec.							
	Annex	-16.6	136.4	-15.4	59.6	-6.8	22.2
	N-Annex	1.1	-	0.8	-	-11.0	22.2
	C-leakage	4.93		4.00		na	
With TFP increase in electricity sec.							
	Annex	-16.7	131.6	-15.4	56.4	-6.8	19.8
	N-Annex	0.0	-	-0.2	-	-11.0	19.8
	C-leakage	0.09		na			

- CO2 Tax ↑ Domest. Price of Output ↑ CO2 from Firms` Import ↑ gco2(coal, others) ↑
  CO2 from Cons. & Inv. ↓ gco2(perto-prod) ↓
- CO2 trade ↑ D-Price of output ↓ CO2 from Firms` Import ↓ gco2(coal, others) ↓
  CO2 from Cons. & Inv. ↑ gco2(petro. Prod) ↑

Results about utility change

		Annex I emissions reduction with no use of flexibility		Emissions reduction with trading among Annex I		Emissions reduction with worldwide emissions trading	
		u	tot	u	tot	u	tot
Without TFP increase in electricity sec.							
	Annex	-0.53	0.06	0.05	0.07	-0.05	-0.01
	N-Annex	-0.06	-0.19	-0.04	-0.13	0.02	0.03
With TFP increase in electricity sec.							
	Annex	-0.25	0.03	0.31	0.04	0.21	-0.03
	N-Annex	0.25	-0.16	0.28	-0.10	0.33	0.05

Summary and Conclusion

- We found that;
  - TFP increase in non energy industries shows that Annex-1 countries were little affected but non Annex-1 countries were a lot.
  - However, such increase resulted in significantly increased welfare gains.
  - TFP increase in Electricity could decrease the price of CO2 trading and increase utility of people via an increase of productivity in all industries.
  - However, it had very small impact on CO2 trade effect.
- It can be said that, as a conclusion, TFP is critical and TFP in all industry has much bigger impact on our economies.

Inclusion of China and India in Annex 1 Countries

Admir Antonio Betarelli Jr.
Aline Souza Magalhaes

West Lafayette, 2011

Introduction

- China and India are important emitters of greenhouse gases.
- In the forthcoming negotiations of the Kyoto Protocol, it is possible that they are included in Annex 1 countries with obligatory emissions' targets.
- So, we've changed the scenario to include China and India in Annex 1 countries.

Experiments, Closure and Shocks

- **Experiment 1**: Emission reduction with emission trading among Annex 1 countries including China and India
- **Experiment 2:** Emission reduction with worldwide emission trading.
- **Shock**: Emission reduction of 17% in China and India as USA and EU.
- **Expected results**: Decline of total emissions and welfare in China and India.

Results

Table 1: Actual reduction in emissions of achieving the emission reduction targets

	% Reduction in Emissions			
	With emission trading among Annex 1 countries		With worldwide emission trading	
	Without China and India	Inclusion of China/India	Without China and India	Inclusion of China/India
1 USA	-15.69	-12.32	-7.02	-10.17
2 EU27	-12.39	-9.59	-5.22	-7.65
3 EEFSU	-20.99	-16.58	-9.52	-13.76
4 JPN	-11.32	-8.67	-4.52	-6.66
5 RoA1	-16.22	-12.81	-7.39	-10.57
6 EEx	1.28	1.09	-4.65	-6.97
7 CHN	**0.26**	**-26.17**	**-16.6**	**-22.73**
8 IND	**0.5**	**-24.65**	**-15.82**	**-21.44**
9 ROW	1.19	1.08	-7.64	-10.68

- Reduction in emissions is driven by the decrease in the activity level in China and India, especially the decrease in firm's demand.
- Emissions' intensity and elasticities are different across the agents and sectors in China and India.

Results

Table 2: Welfare effects of implementing the emission

	% Reduction in Welfare	
	With emission trading among Annex 1 countries	With worldwide emission trading
1 USA	-0.09	-0.06
2 EU27	-0.06	-0.01
3 EEFSU	0.68	0.22
4 JPN	-0.09	-0.04
5 RoA1	-0.39	-0.34
6 EEx	-0.36	-0.56
7 CHN	**0.04**	**-0.05**
8 IND	**-0.06**	**-0.02**
9 ROW	0.07	0.1

- There is an unexpected result. Despite the significant reduction of emissions and activity level in China (-17%), welfare has increased. Why??

Results

- Decomposition of welfare shows us that the contribution of carbon trading is driving the result.
- The cost structure of Chinese Economy and substitution elasticities allows it to have lower abatement costs. Therefore, China is able to sell more tradable permits to other countries and get more trading revenue.
- But it's still necessary to dig in and to do a detailed analysis…

Table 3: Decomposition of Welfare

WELFARE	Carbon trading	Allocative effects	Terms of trade	Changes in the price of cgds	Total
1 USA	-3344.02	-10380.04	3760.09	313.41	-9650.57
2 EU27	-3467.91	-7056.05	4184.08	-119.35	-6459.24
3 EEFSU	7176.28	-1228.44	-723.05	15.89	5240.68
4 JPN	-2765.17	-2577.66	1846.24	-206.44	-3703.03
5 RoA1	-3357.62	-2580.3	-2093.24	5.12	-8026.04
6 EEx	0	939.87	-10250.02	275.63	-9034.51
7 CHN	**4763.9**	**-5521.36**	**1411.56**	**-97.78**	**556.32**
8 IND	**956.02**	**-2090.84**	**756.14**	**11.44**	**-367.23**
9 ROW	0	1311.53	1081.49	-197.35	2195.67
Total	-38.53	-29183.3	-26.72	0.58	-29248

*others components were excluded (null values)

The impacts of oil supply control under the worldwide emissions trading scheme

Oh Sang Kwon

Alex Hislop

Motivation

- “Perfect World” – worldwide emission trading
- Base case: EEX experiences welfare reduction and TOT decreases
    - Oil price has declined

- EEX can take action!
- What are the impacts of EEX imposing an output tax to restrict oil production?
- Closure: swap qo(“oil”,”eex”) = to(“oil”,”eex”)
    - *Shock qo(“oil”,”eex”) = -10*

Impacts on Carbon Price and Welfare (% change from the base data)

	No Output Tax			**Output Tax (10% Reduction in EEX's Oil Production)**		
	Carbon Price ($/T)	**Welfare (%)**	**TOT (%)**	**Carbon Price($/T)**	**Welfare (%)**	**TOT %)**
USA		-0.05	0.18		-0.17	-0.33
EU27		-0.01	0.07		-0.20	-0.12
EEFSU		0.09	-0.33		0.79	1.2
JPN	22.2	-0.03	0.26	19.7	-0.23	-0.65
RoA1		-0.23	-0.22		-0.14	0.12
EEx		-0.37	-0.7		0.59	1.45
CHN		0.22	0.13		0.02	-0.28
IND		0.16	0.55		-0.42	-0.89
ROW		0.05	0.14		-0.28	-0.36
World Oil Price (%)	-1.44			5.53		

Change in Welfare Decomposition due to the Output Tax in EEX (%)

	Welfare Decomposition			
WELFARE	**Emission Td. Revenue**	**Allocative Eff.**	**TOT**	**Total**
1 USA	0.16	-0.88	-2.66	-2.43
2 EU27	0.16	-13.20	-2.58	-25.24
3 EEFSU	-0.14	0.85	4.59	7.39
4 JPN	0.18	-3.97	-3.55	-6.79
5 RoA1	0.13	-0.84	1.48	1.40
6 EEx	-0.25	-0.76	3.05	2.59
7 CHN	-0.18	0.10	-2.98	-0.93
8 IND	-0.15	-1.95	-2.89	-3.59
9 ROW	-0.04	-2.46	-3.51	-6.25
Total	-0.55	-1.91	5.68	-1.90

Impacts of Oil Output Tax on Carbon Emission Reduction (%)

	No Tax	Tax	Difference
USA	7.02	7.51	0.49
EU27	5.22	5.75	0.53
EEFSU	9.52	9.08	-0.44
JPN	4.52	6.36	1.84
RoA1	7.39	7.84	0.45
EEx	4.65	3.96	-0.69
CHN	16.6	15.4	-1.20
IND	15.82	15.19	-0.63
ROW	7.64	8.27	0.63
Annex1	6.78	7.22	0.45
Non-Annex1	11.04	10.46	-0.58
Total	8.64	8.64	-0.00

Impacts of Oil Output Tax on Price Change Rates (%)

Market prices	No Tax		Tax		Difference	
	USA	EEx	USA	EEx	USA	EEx
land	-0.01	0.41	0.26	4.38	0.27	3.97
unsklab	0.28	0.01	0.48	0.51	0.2	0.5
sklab	0.29	0.03	0.48	0.55	0.19	0.52
capital	-0.2	-1.08	-0.11	-3.35	0.09	-2.27
natlres	-7.39	-3.89	2.62	-27.78	10.01	-23.89
Agriculture	0.31	0.11	0.68	0.69	0.37	0.58
Coal	-1.09	-1.27	-0.76	-2.17	0.33	-0.9
Oil	-1.38	-1.52	3.61	6.99	4.99	8.51
Gas	-0.87	-1.37	-0.47	-1.42	0.4	-0.05
Oil_pcts	-0.65	-0.07	4.6	6.1	5.25	6.17
Electricity	4.91	5.02	4.82	5.91	-0.09	0.89
En_Int_ind	0.59	0.86	1.05	0.89	0.46	0.03
Oth_ind_ser	0.32	0.1	0.58	-0.19	0.26	-0.29
CGDS	0.32	0.21	0.56	0.07	0.24	-0.14

Optimal Welfare (EEX)

Quantity Reduction(%)	Welfare Change (u)
10	0.59
20	1.22
30	1.41
40	1.13
55	-0.34

Summary and Conclusion

1. Worldwide emission trading has been suggested as the most efficient and ideal mechanism of reducing Co2 emission.
2. Whatever carbon reduction mechanism is chosen, energy exporting countries may obtain welfare loss, mainly due to the deterioration of their terms of trade.
3. The potential negative gain may induce them to take some actions to cut oil supply (e.g. via output tax on oil).
4. Those actions enhance EEx's terms of trade and may make the bloc obtain positive gains, but generate additional distortions in the world market.
5. Even China and India which can sell permits may get loss by the introduction of the mechanism if EEx controls its output (or price) of oil.

GTAP-E Small Group Presentation

Dave Gustafson

Hao Luan

Small Project Summary

- We attempted to identify the carbon taxation and trading scheme that has the maximum net sustainability benefit, when considering both economic factors (modeled within GTAP-E) and the environmental/social harm avoided by reducing carbon emissions.
- We calculated net sustainability benefit as a function of Annex I target carbon reductions
  – Targets were varied from 5% to 90%, while allowing worldwide emission trading.

"Social Cost of Carbon"

- **Definition:**
  "the lifetime damage costs associated with incremental greenhouse gas emissions" [1]
- **Recently estimated values (and ranges):**
  - **Stern Review (2007): $340/tonne ($65-$905)** [2]
  - **UK Government (2009): $84/tonne ($41-$124)** [1]
  - **US Government (2010): $21/tonne ($5-$65)** [3]

[1] UK Department of Energy and Climate Change (2009). *Carbon Valuation in UK Policy Appraisal: A Revised Approach.*
[2] *Yale Symposium on the Stern Review* (2007). This is the base case result. Other experiments gave central values from $70 to $505.
[3] US Department of Energy (2010). *Social Cost of Carbon for Regulatory Impact Analysis under Exec. Order 12866 13.*

Quantifying Net Sustainability Benefits of Carbon Reductions

- **Components of sustainability:**
  - Economic ⟵ assume equal to EV (in GTAP-E)
  - Environmental
  - Social

  (Environmental and Social:) assume both are captured by the "Social Cost of Carbon"

$$SUS(\mathit{reg}) = EV(\mathit{reg}) + (\mathit{SCC}(\mathit{reg})*CO2red)$$

We did not have information on the regional variation of *SCC*, so we assumed a constant value worldwide

Use of Shocks to Simulate Different Annex I Carbon Reduction Targets

Shock file similar to example provided in baseline simulation:[1]

shock gco2q("USA") = -17;

shock gco2q("EU27") = -17;

shock gco2q("JPN") = -30;

shock gco2q("RoA1") = -40;

EV = -16.8 B USD
Total Carbon Reduction = 0.667 GtC
World Carbon Price = $24.95

Example shock file from our small project (20% Annex I target):

shock gco2q("USA") = -20;

shock gco2q("EU27") = -20;

shock gco2q("JPN") = -20;

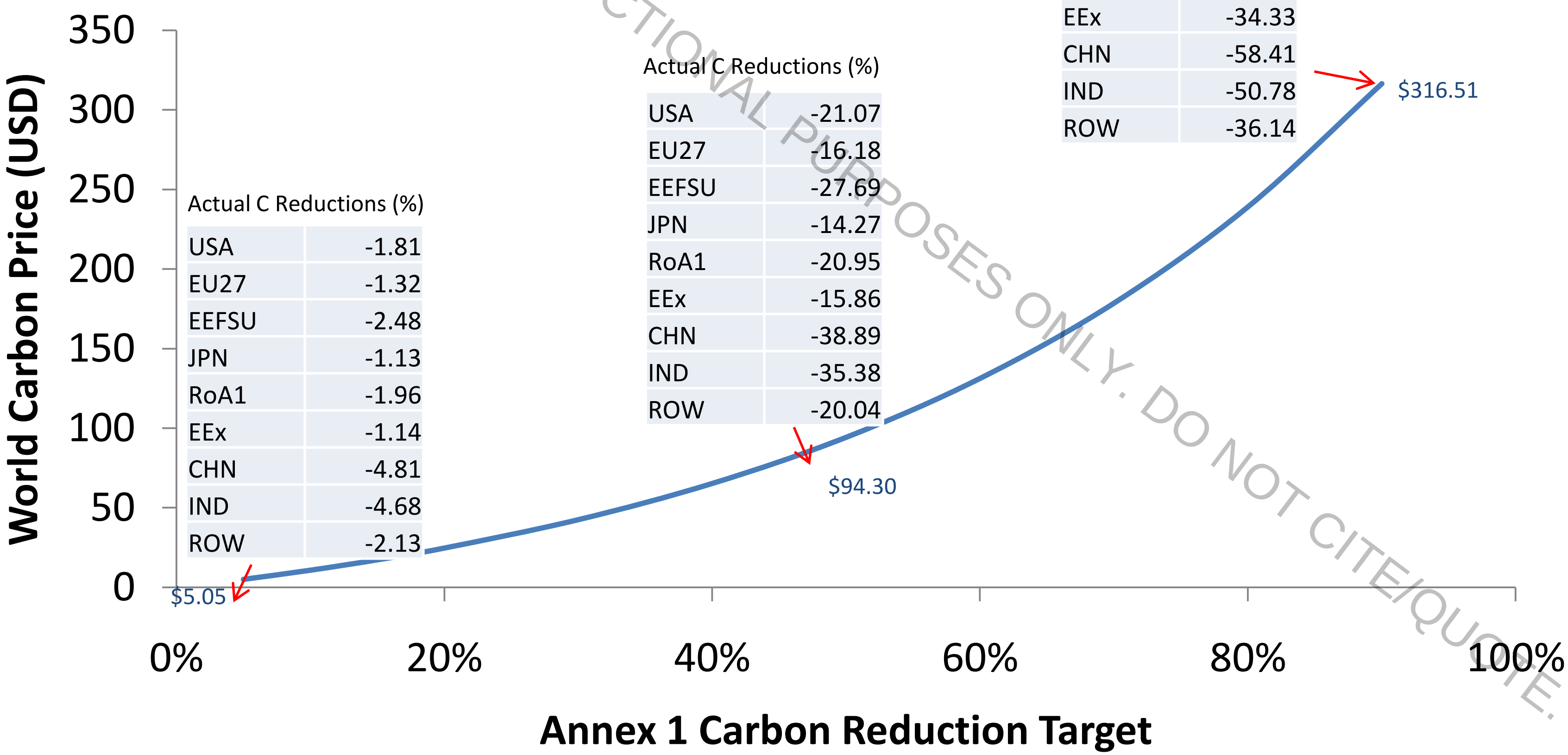
shock gco2q("RoA1") = -20;

EV = -16.6 B USD
Total Carbon Reduction = 0.662 GtC
World Carbon Price = $24.71

We found that EV and actual carbon reductions were insensitive to re-allocation of regional carbon reduction targets, under the assumption of worldwide trading of emissions – thus, for simplicity we kept all Annex I targets equal to each other

[1] WTR case with EEFSU +9% target removed.

Major Carbon Reductions Require a Much Higher World Carbon Price



Actual C Reductions (%)

USA	-1.81
EU27	-1.32
EEFSU	-2.48
JPN	-1.13
RoA1	-1.96
EEx	-1.14
CHN	-4.81
IND	-4.68
ROW	-2.13

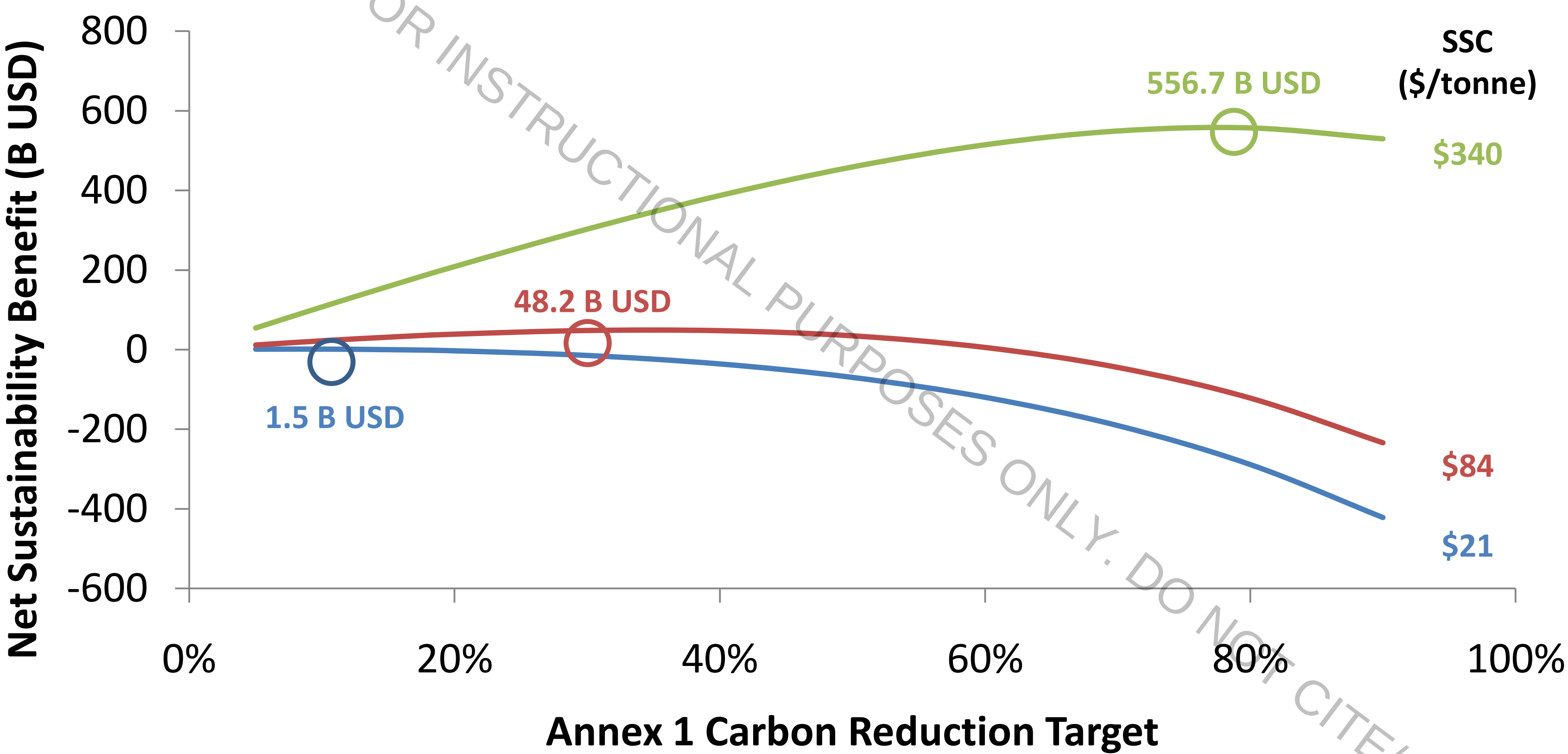
Actual C Reductions (%)

USA	-21.07
EU27	-16.18
EEFSU	-27.69
JPN	-14.27
RoA1	-20.95
EEx	-15.86
CHN	-38.89
IND	-35.38
ROW	-20.04

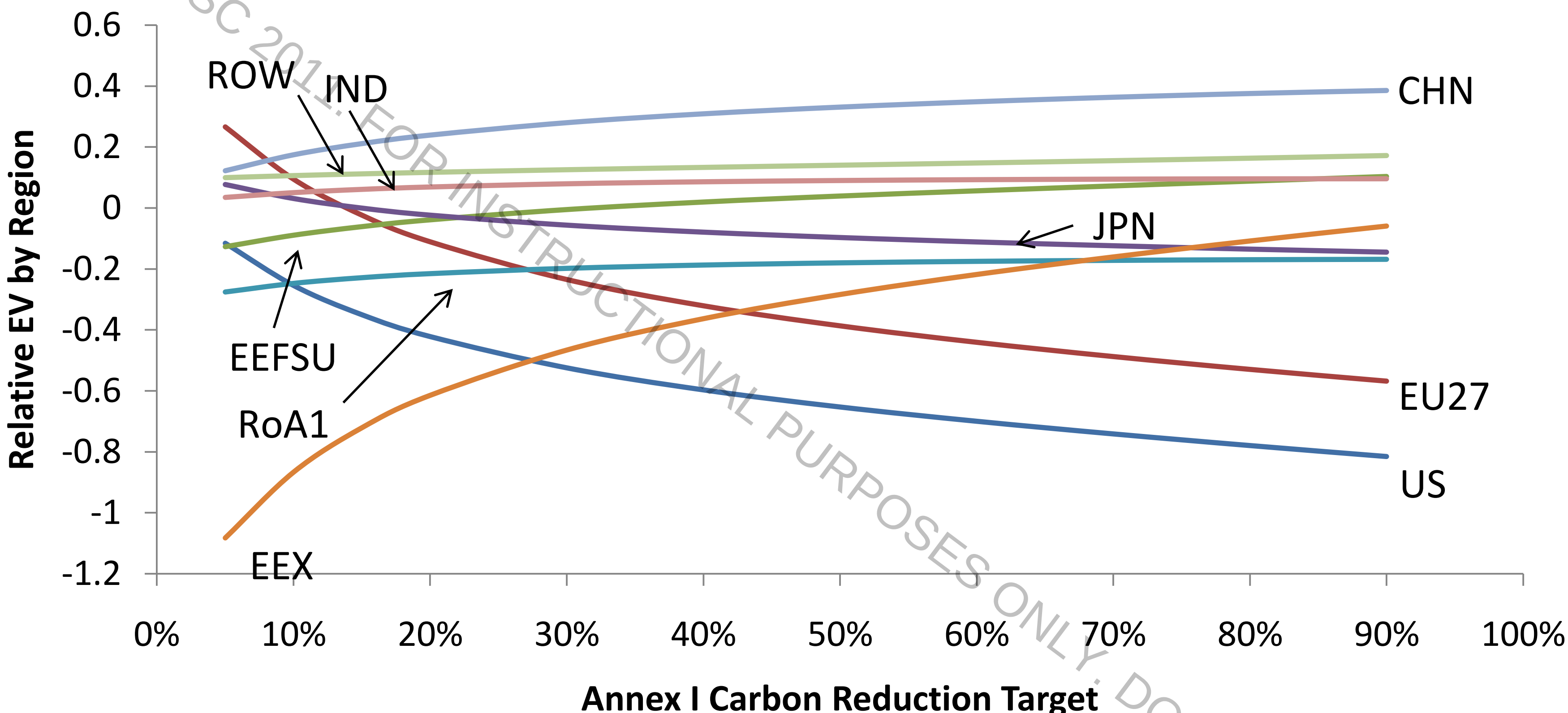
Actual C Reductions (%)

USA	-42.25
EU27	-32.67
EEFSU	-48.85
JPN	-30.58
RoA1	-40.23
EEx	-34.33
CHN	-58.41
IND	-50.78
ROW	-36.14

Optimal Carbon Reduction Target Depends on Social Cost of Carbon



Regional Variation



- **Energy Exporters are biggest losers at low targets (< 30%)**
- **US is the biggest loser at high targets (> 30%)**
- **China is the biggest winner for targets > 10%**

Conclusions

- **Results are insensitive to re-allocation of regional carbon reduction targets**
  - **Assuming worldwide trading of carbon emissions**
- **Major carbon reductions require very high world carbon prices**
- **Optimal carbon target highly dependent on actual social cost of carbon**
- **Interesting regional effects with increases in the price of carbon**