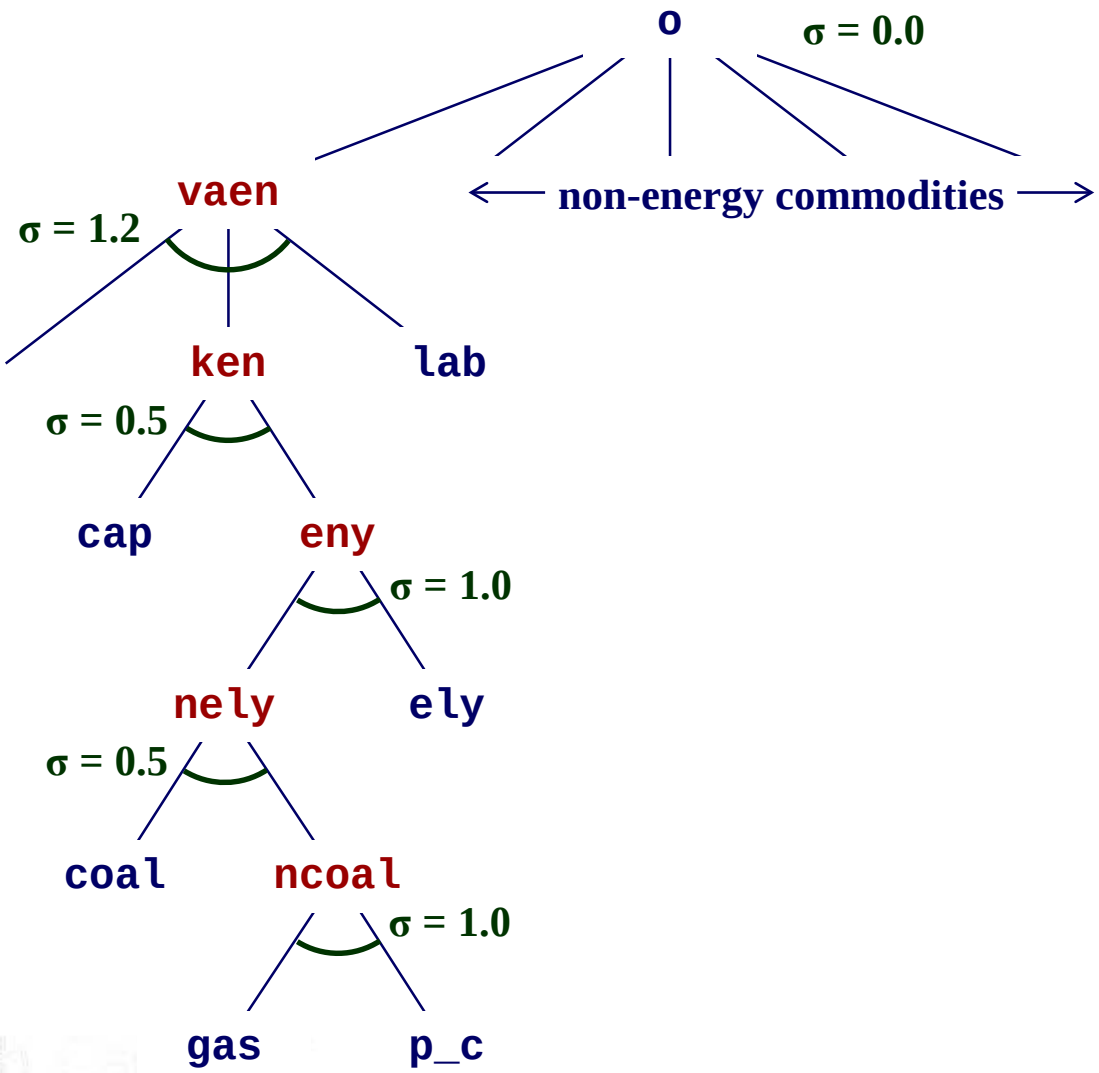
The GTAP-E Model:
An Extension of the GTAP Model for Energy and Climate Change Analysis

August 12, 2016

West Lafayette, USA

GTAP-E production structure



Emission accounting

- **intermediate usage:**
  - `CO2DF(i,j,r)` and `CO2IF(i,j,r)`
  - `gco2fd(i,j,r)` and `gco2fm(i,j,r)`
- **private consumption:**
  - `CO2DP(i,r)` and `CO2IP(i,r)`
  - `gco2pd(i,r)` and `gco2pm(i,r)`
- **government consumption:**
  - `CO2DG(i,r)` and `CO2IG(i,r)`
  - `gco2gd(i,j,r)` and `gco2gm(i,j,r)`

Carbon taxation

$PA = T_{nc} \times PM + TR_c \times EI$, where:

PA	≡	agents' price
PM	≡	market price
T_{nc}	≡	power of non-carbon tax
TR_c	≡	carbon tax rate ($/tC)
EI	≡	emission intensity (tC/quantity unit)

Emission trading

- **emissions accounting and carbon tax at regional and bloc levels:**
  - actual emissions:
    - coefficients `CO2T(r)` and `CO2TB(b)`
    - variables `gco2t(r)` and `gco2tb(b)`
  - emissions quota:
    - coefficients `CO2Q(r)` and `CO2QB(b)`
    - variables `gco2q(r)` and `gco2qb(b)`
  - absolute change in real carbon tax: variables `RCTAX(r)` and `RCTAXB(r)`

	With no use of the flexibility mechanisms		With emission trading among Annex 1 countries		With worldwide emission trading	
Region	% Reduction in emission	2007 usd per tonne CO2	% Reduction in emission	2007 usd per tonne CO2	% Reduction in emission	2007 usd per tonne CO2
USA	-0.08	0.45	-0.09	0.45	-0.04	0.14
EU27	-0.17	0.23	-0.11	0.16	-0.01	0.07
EEFSU	-0.64	-1.15	0.37	-0.47	-0.06	-0.31
Jpn	-0.78	1.27	-0.2	0.46	-0.03	0.2
RoA1	-1.25	-0.07	-0.55	-0.33	-0.17	-0.12
EEx	-0.65	-1.38	-0.45	-0.96	-0.22	-0.5
Chn	-0.1	0.01	-0.02	0.09	0.11	0.12
Ind	0.19	0.32	0.14	0.25	0.21	0.22
RoW	0	-0.06	0.01	-0.02	0.01	0.05

	With no use of the flexibility mechanisms		With emission trading among Annex 1 countries		With worldwide emission trading	
Region	% Reduction in emission	2007 usd per tonne CO2	% Reduction in emission	2007 usd per tonne CO2	% Reduction in emission	2007 usd per tonne CO2
USA	-17	24	-17.4	24.2	-6.3	6.7
EU27	-17	40.1	-11.8	24.3	-3.9	6.7
EEFSU	1.7	0	-20.6	24.2	-7.3	6.7
Jpn	-30	121	-10.5	24.3	-3.4	6.7
RoA1	-40	125.5	-15.1	24.3	-5.3	6.7
EEx	1.3	0	0.8	0	-4.4	6.7
Chn	0.4	0	0.3	0	-15.8	6.7
Ind	-0.3	0	-0.1	0	-21.9	6.7
RoW	1.3	0	0.9	0	-5.8	6.7
Annex 1	-16.8		-15.6		-5.5	
Non-Annex	0.8		0.5		-11.4	
Leakage	rate					
(incl.	EEFSU)	5.7	na		na	
Leakage	rate					
(excl.	EEFSU)	4.1	3.1		na	

GTAP-E Group

- Surface Coal Mining, Land & Agriculture
- Effects of a Natural Gas and Oil Export Shock
- Impacts of Emissions Reduction Under Paris Agreement
- World post tax energy subsidies elimination: a GTAP-E based analysis

Surface Coal Mining, Land & Agriculture

GTAP-E Group

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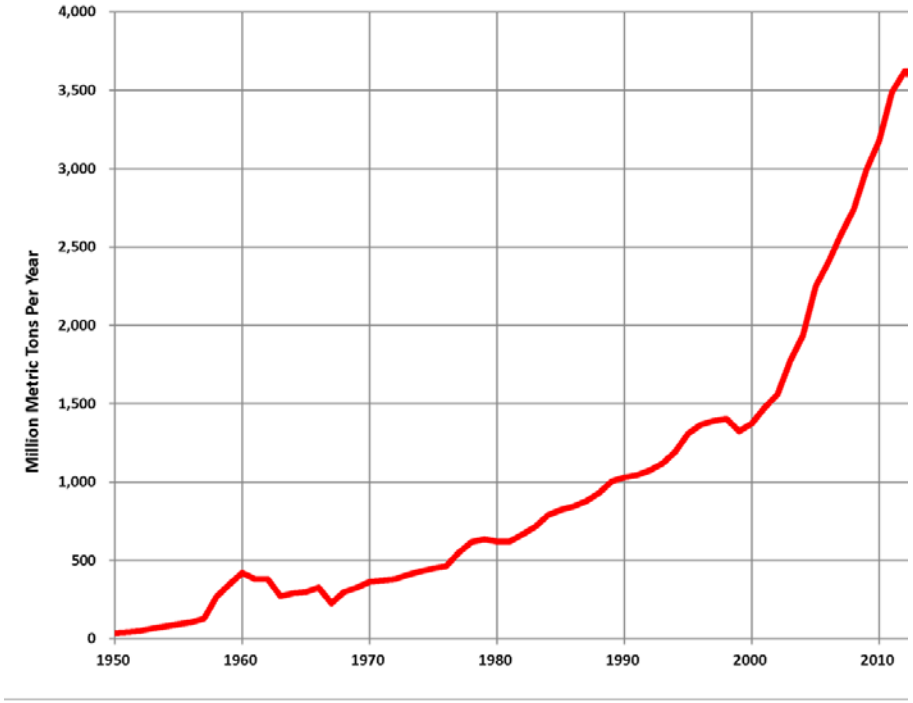
The Story

Rapid economic growth of China

- Direct and indirect demand for coal increase, mainly satisfied by domestic supply
- Domestic coal mining expands
- Surface mining dominates due to low production cost



Surface Mining

1. Reduction in available land in the short run
2. Decrease in land productivity in the long run

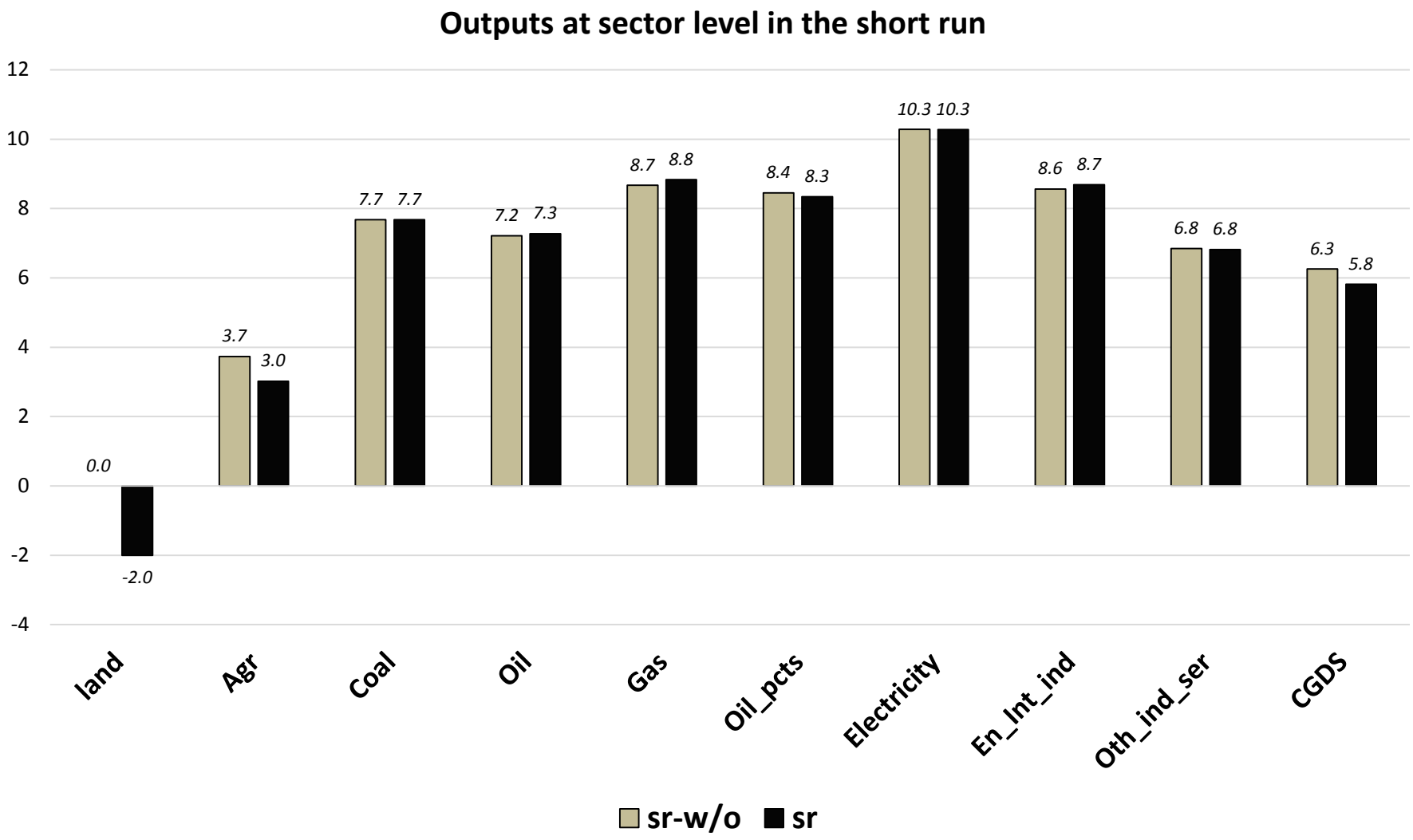
Objective & Scenarios

Objective

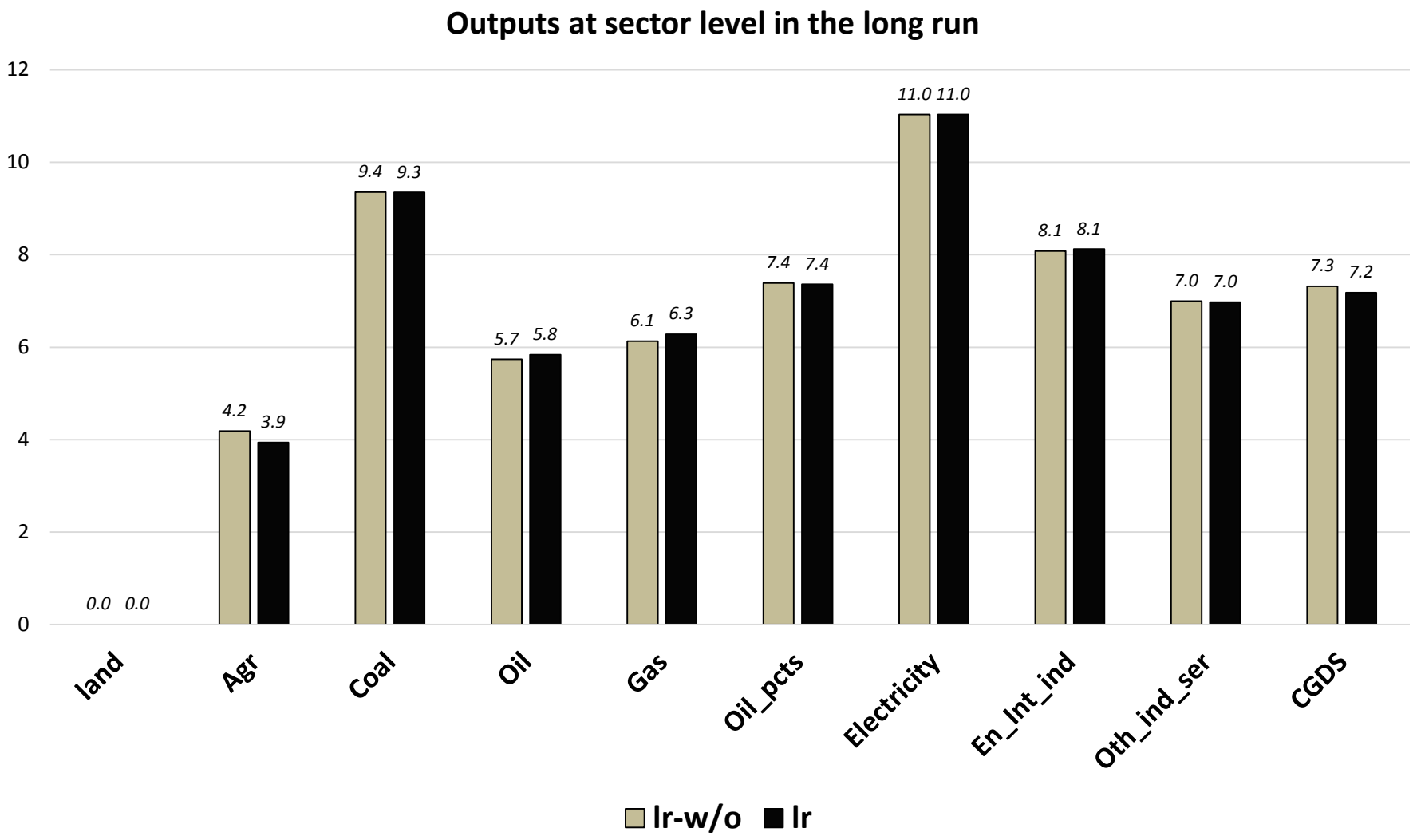
- To analyze the impacts of surface coal mining on agriculture and other sectors

Table 1. Scenarios				
	Short-run Scenario		Long-run Scenario	
	w/o reduction in available land	with reduction in available land	w/o decrease in land productivity	with decrease in land productivity
Exogenous	qo("Capital","CHN") = 15	qo("Capital","CHN") = 15 qo("land","Agr","CHN") = -2	qo("Capital","CHN") = 15	qo("Capital","CHN") = 15 afall("land","Agr","CHN") = -1
Parameters	• Land, Capital and Natural recourses sluggish • Smaller substitution elasticity in the Value-Added-Energy Nest of CHN sectors		• Default	

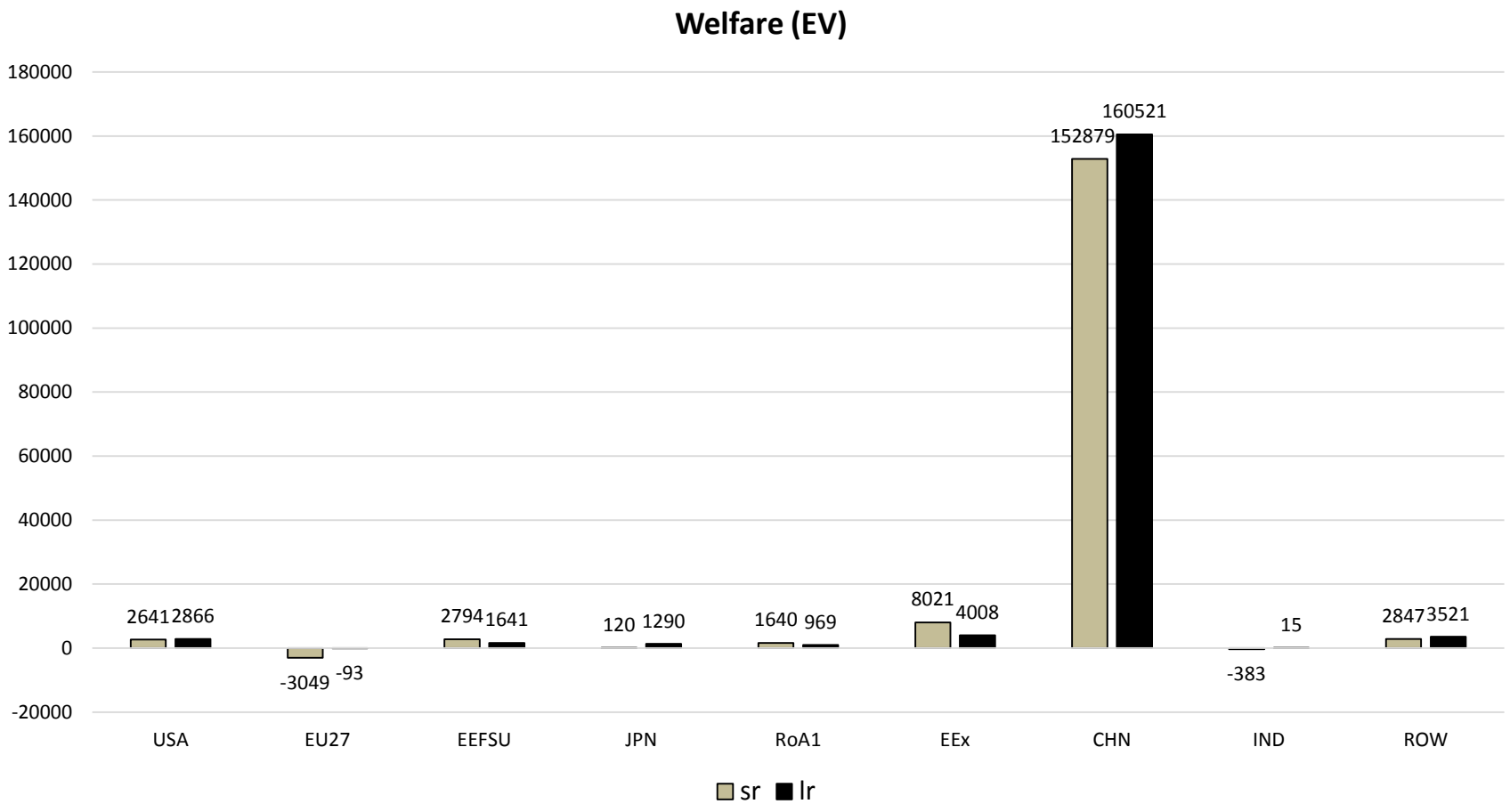
Simulation Results (1)



Simulation Results (2)



Simulation Results (3)



Sensitivity tests

Table 2. Sensitivity tests

	Reduction in available land: qo("land","CHN") = [-1,-3]			Decrease in land productivity: afall("land","Agr","CHN") = [-0.5,-1.5]			
		Mean	**s.d.**	**Ratio**		**Mean**	**s.d.**	**Ratio**
qo(j,CHN)	**Agr**	3.02	0.15	20	**Agr**	3.94	0.05	77
	Coal	7.67	0.00	76743	**Coal**	9.35	0.00	5699
	Oil	7.27	0.01	573	**Oil**	5.84	0.02	274
	Gas	8.83	0.04	251	**Gas**	6.28	0.03	198
	Oil_pcts	8.34	0.02	361	**Oil_pcts**	7.36	0.01	1278
	Electricity	10.27	0.00	5464	**Electricity**	11.04	0.00	551767
	En_Int_ind	8.69	0.03	326	**En_Int_ind**	8.12	0.01	865
	Oth_ind_ser	6.81	0.01	926	**Oth_ind_ser**	6.97	0.01	1298
	CGDS	5.82	0.09	61	**CGDS**	7.18	0.03	247

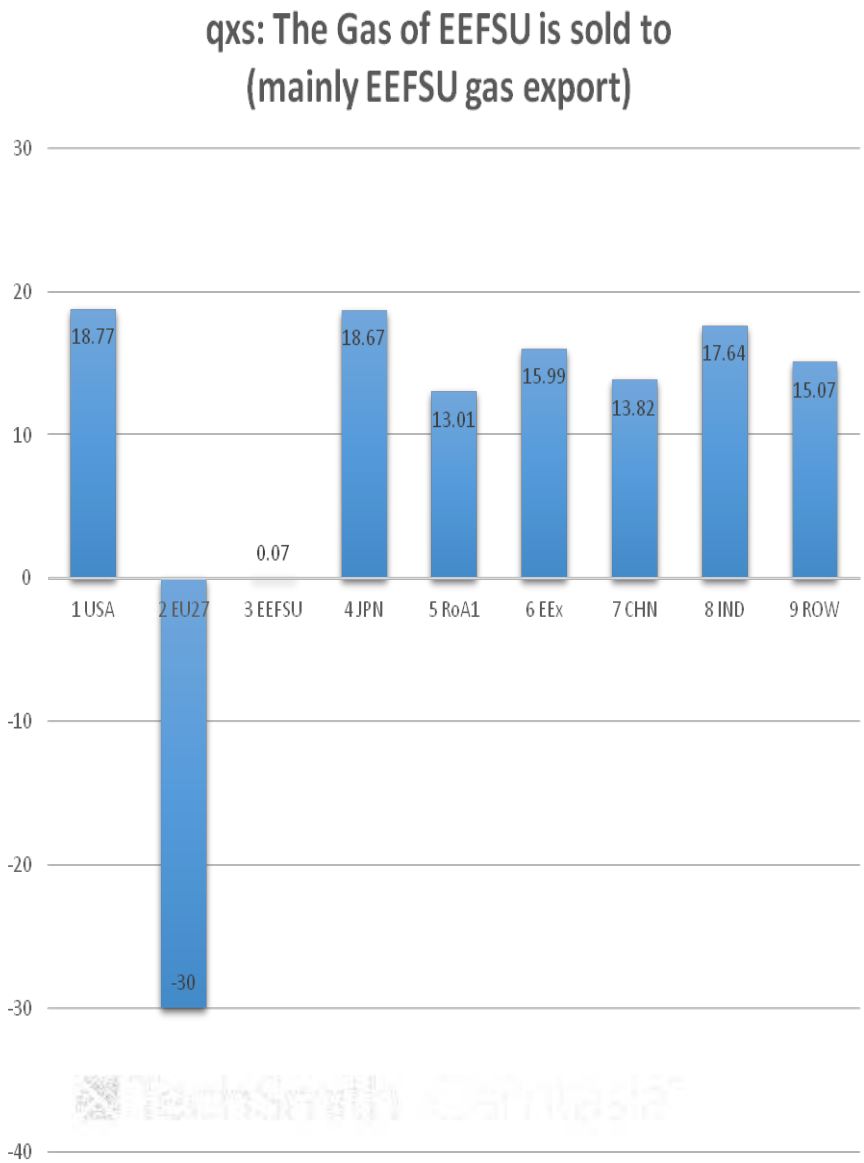
Effects of a Natural Gas and Oil Export Shock

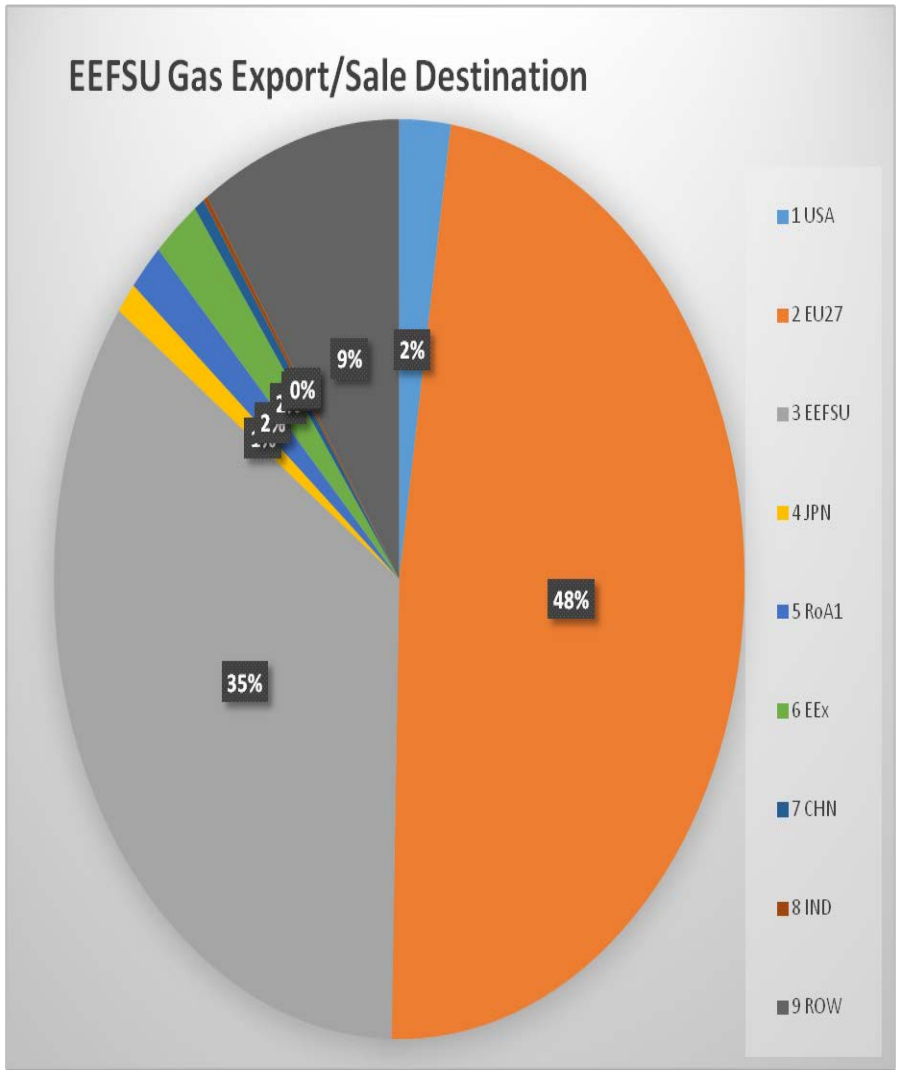
Nisal Herath

Susan Xu

- Motivation: Russia entered into a series of gas disputes with European countries, including reduction of natural gas export to the Europe.
- If oil exporting countries want to increase the price, they would decrease the supply of oil.
- To simulate these scenarios, there was a 30% reduction of natural gas from EEFSU to EU27, also there was 30% reduction of from EEx to all regions.

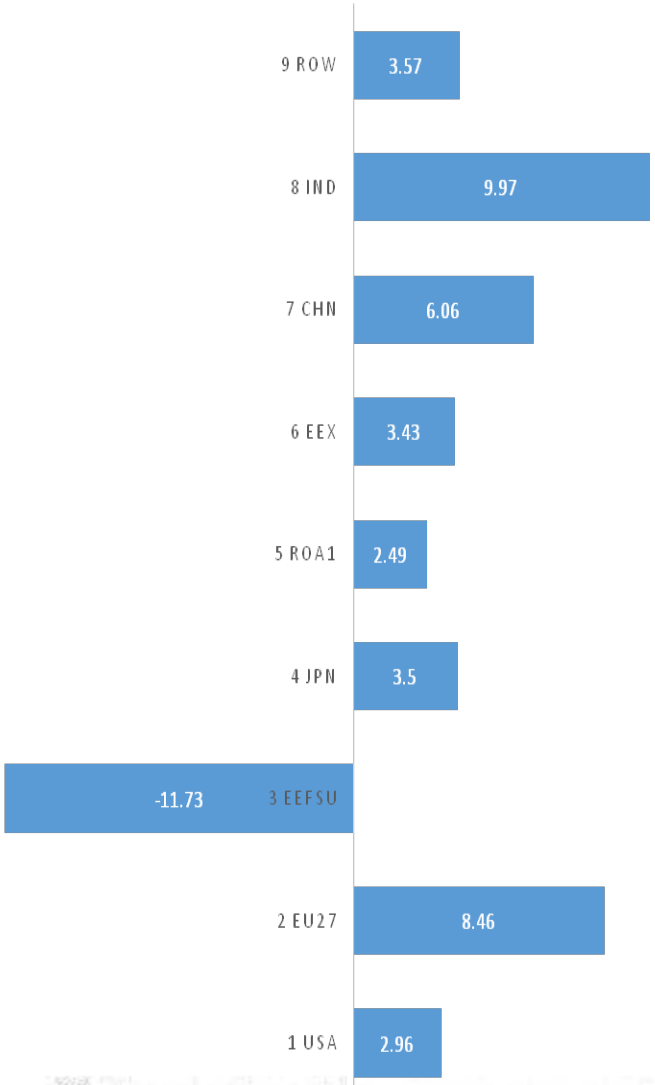
Background: *Russia reduced 30% of natural gas export to EU27*



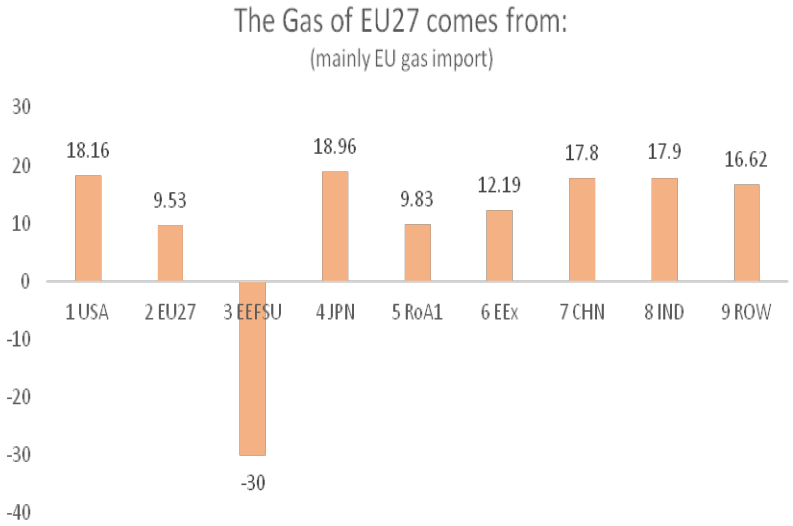


After the shock

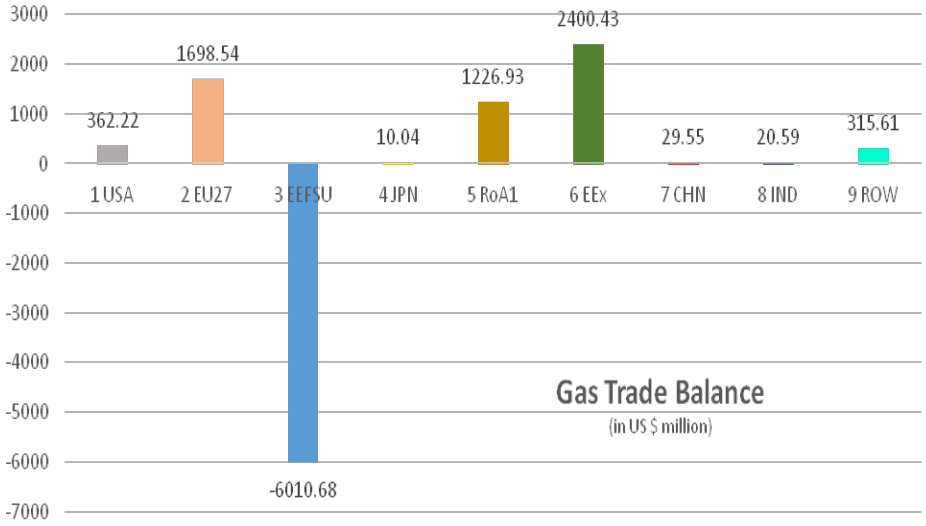
qxw: The aggregate gas export of EEFSU



qim: The aggregate gas import into EU27



DTABLi: Trade Balance in Gas



qxs: Gas export sales from EEFSU to EU27

qxs(gas,EEFSU,EU27)

= -*ams*(gas,EEFSU,EU27) + qim(gas,EU27)

Expansion effect:
qim = -1.50

- ESUBM(gas) * [pms(gas,EEFSU,EU27) - *ams*(gas,EEFSU,EU27) - pim(gas,EU27)]

Substitution effect:
Pim = -0.37
Pms = 1.77
ESUBM = 30.30

- Expansion effect & substitution effect: same direction.
- Substitution effect: dominating

Welfare Impact

WELFARE	1 co2trd	2 alloc_A1	3 endw_B	4 tech_C1	5 pop_D1	6 tot_E1	7 IS_F1	8 pref_G1	Total
2 EU27	0	-105.612	0	0	0	-334.871	-12.606	0	-453.09
3 EEFSU	0	-3324.02	0	0	0	-256.794	83.603	0	-3497.21

CNTalleffl	1 pfacttax	2 prodtax	3 inputtax	4 contax	5 govtax	6 xtax	7 mtax	Total
2 EU27	-2.522	11.85	-18.138	-99.806	0.008	1.916	1.083	-105.612
3 EEFSU	4.172	-263.975	68.404	-184.553	-0.898	-2824.8	-122.377	-3324.02

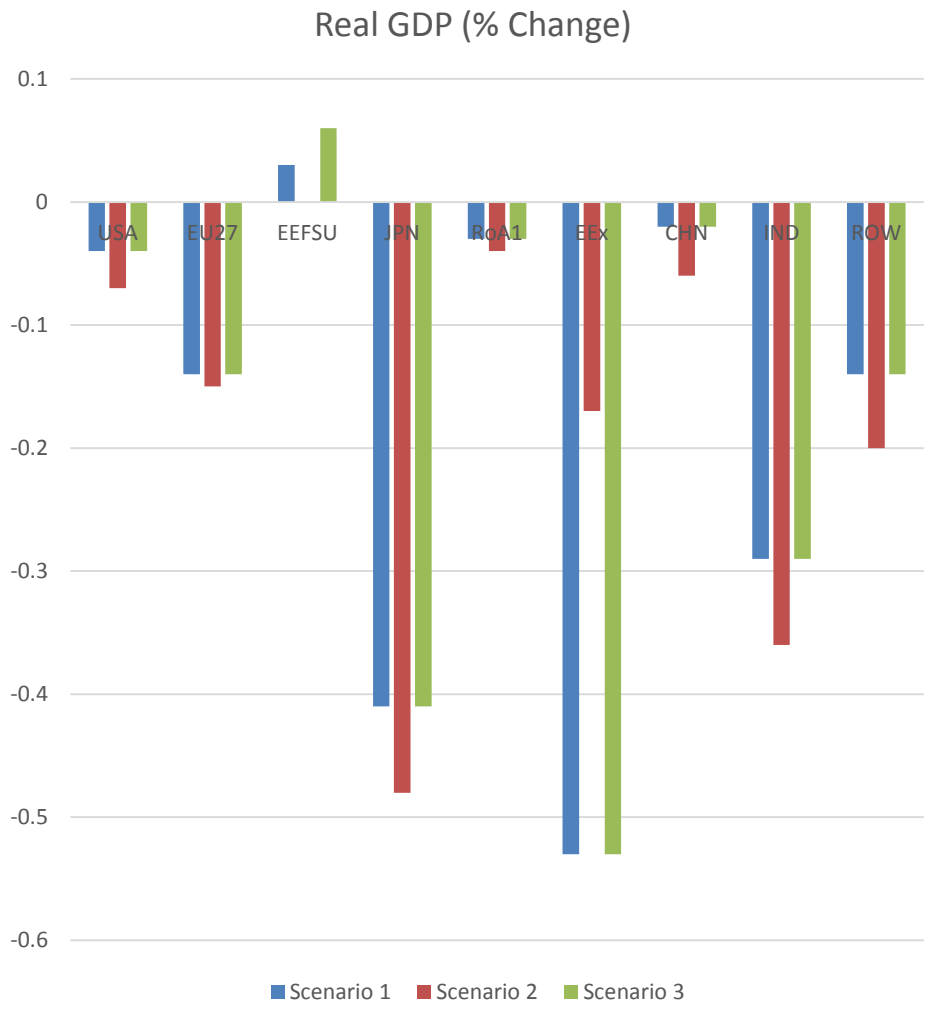
PRIVATE	1 welcnt	2 dvol	3 taxrateb	4 taxrateu	Total
2 EU27	-88.476	-123.523	113.147	113.147	14.295
3 EEFSU	-1.275	2.595	42.274	42.274	85.867

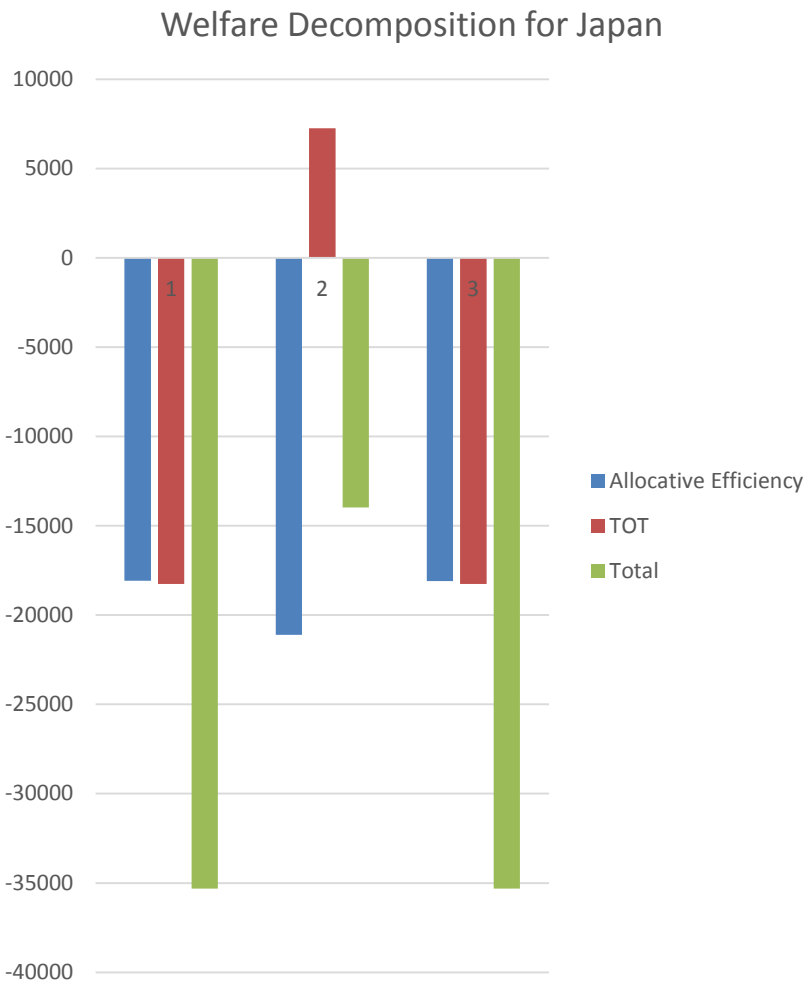
TRADE	1 welcnt	2 dvol	3 taxrateb	4 taxrateu	Total
2 EU27	0	938.983	0	0	938.983
3 EEFSU	-3366.74	-4502.1	42.203	43.461	-7783.18

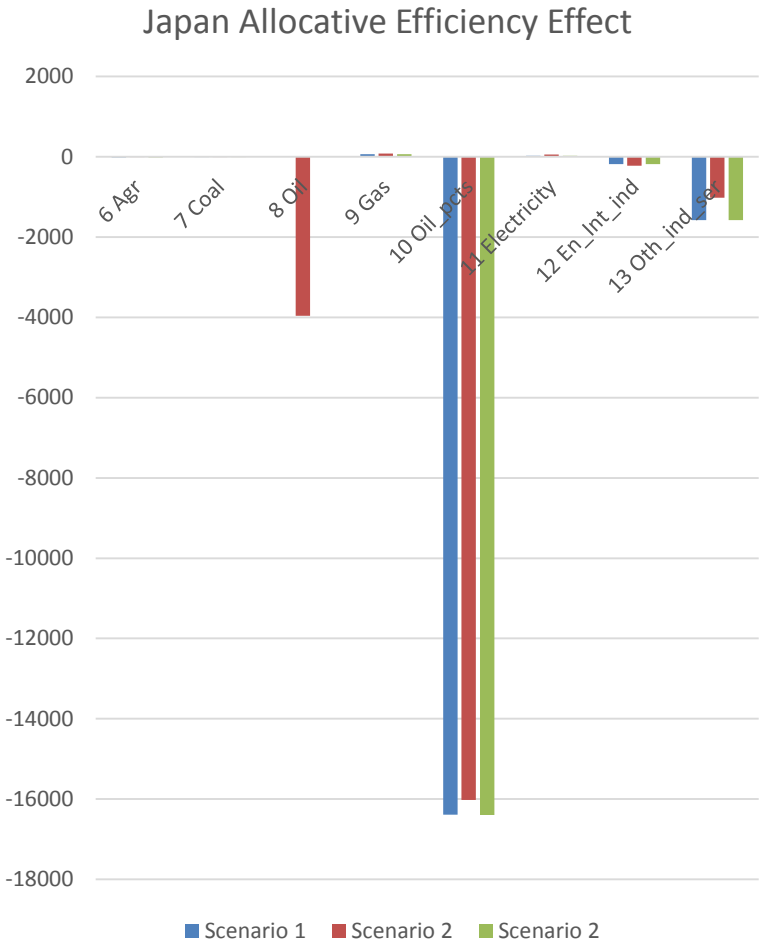
Scenario 1: 30% decrease in Oil exports from EEx region with rents going to exporter

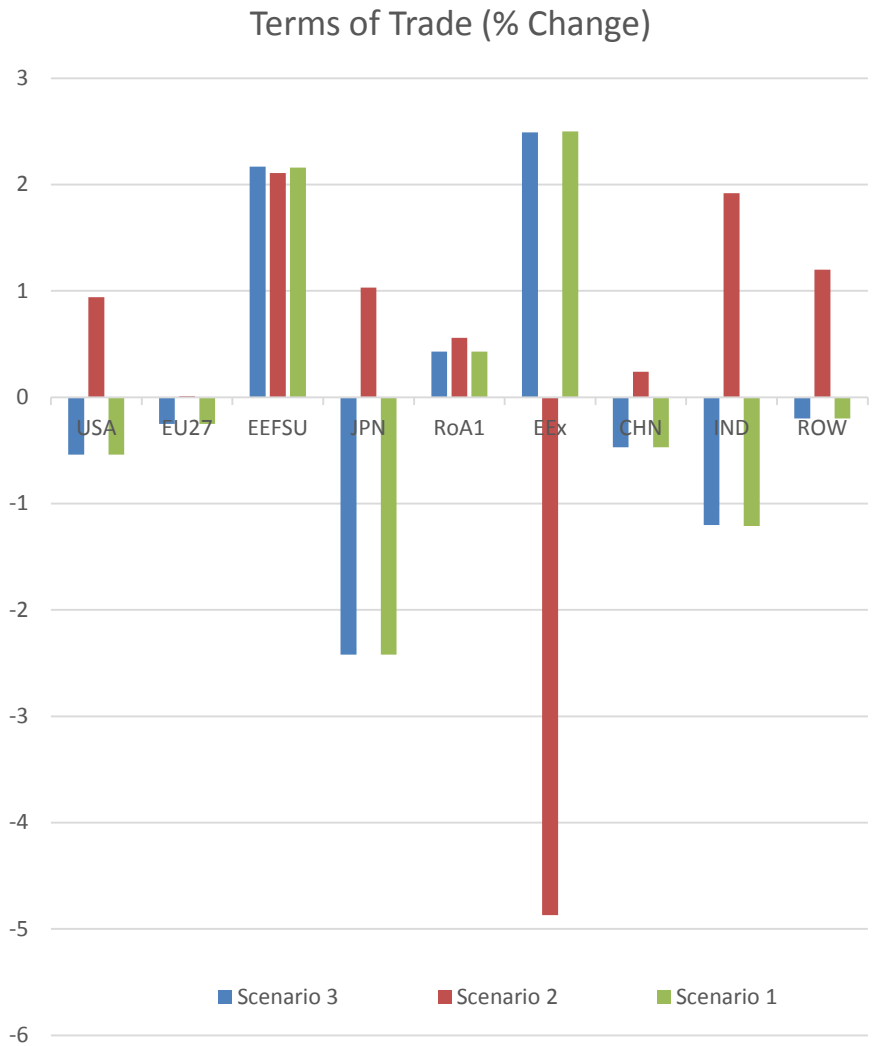
Scenario 2: 30% decrease in Oil exports from EEx region with rents going to importer

Scenario 3: 30% decrease in Oil exports from EEx region with rents going to exporter and 30% decrease in Natural gas exports from EEFSU region to EU27

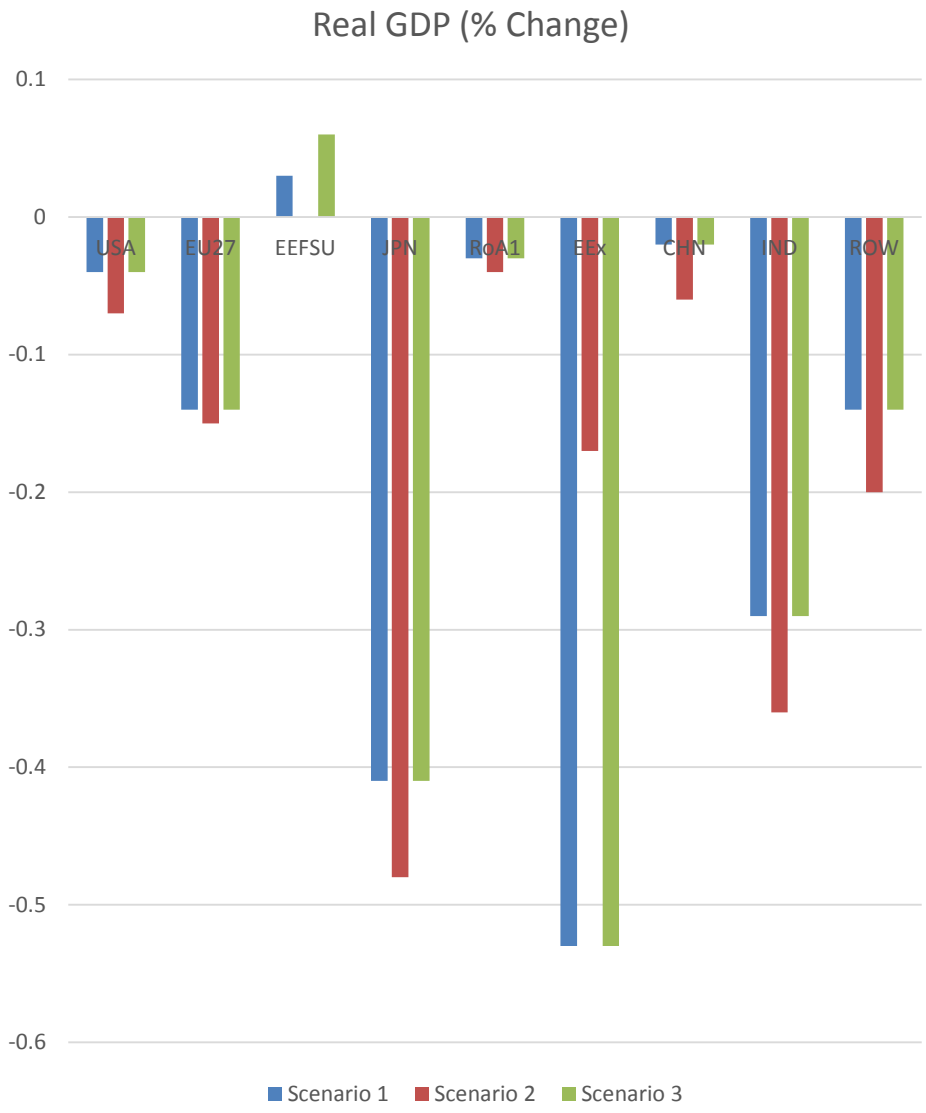


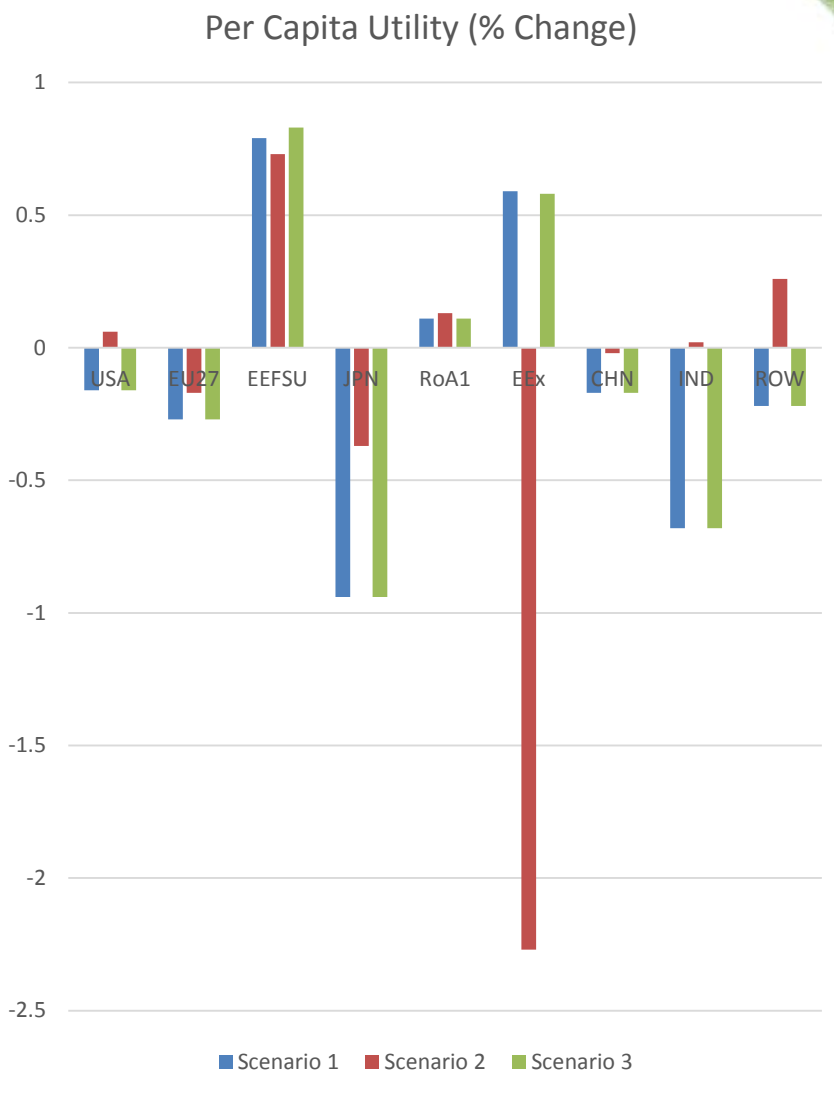

Welfare Decomposition for Japan
10000
5000
0
-5000
-10000
-15000
-20000
-25000
-30000
-35000
-40000
1
2
3
Allocative Efficiency
TOT
Total


Japan Allocative Efficiency Effect
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
6 Agr
7 Coal
8 Oil
9 Gas
10 Oil_pcts
11 Electricity
12 En_Int_ind
13 Oth_ind_ser
Scenario 1
Scenario 2
Scenario 2



An improvement in the terms of trade is not captured in GDP





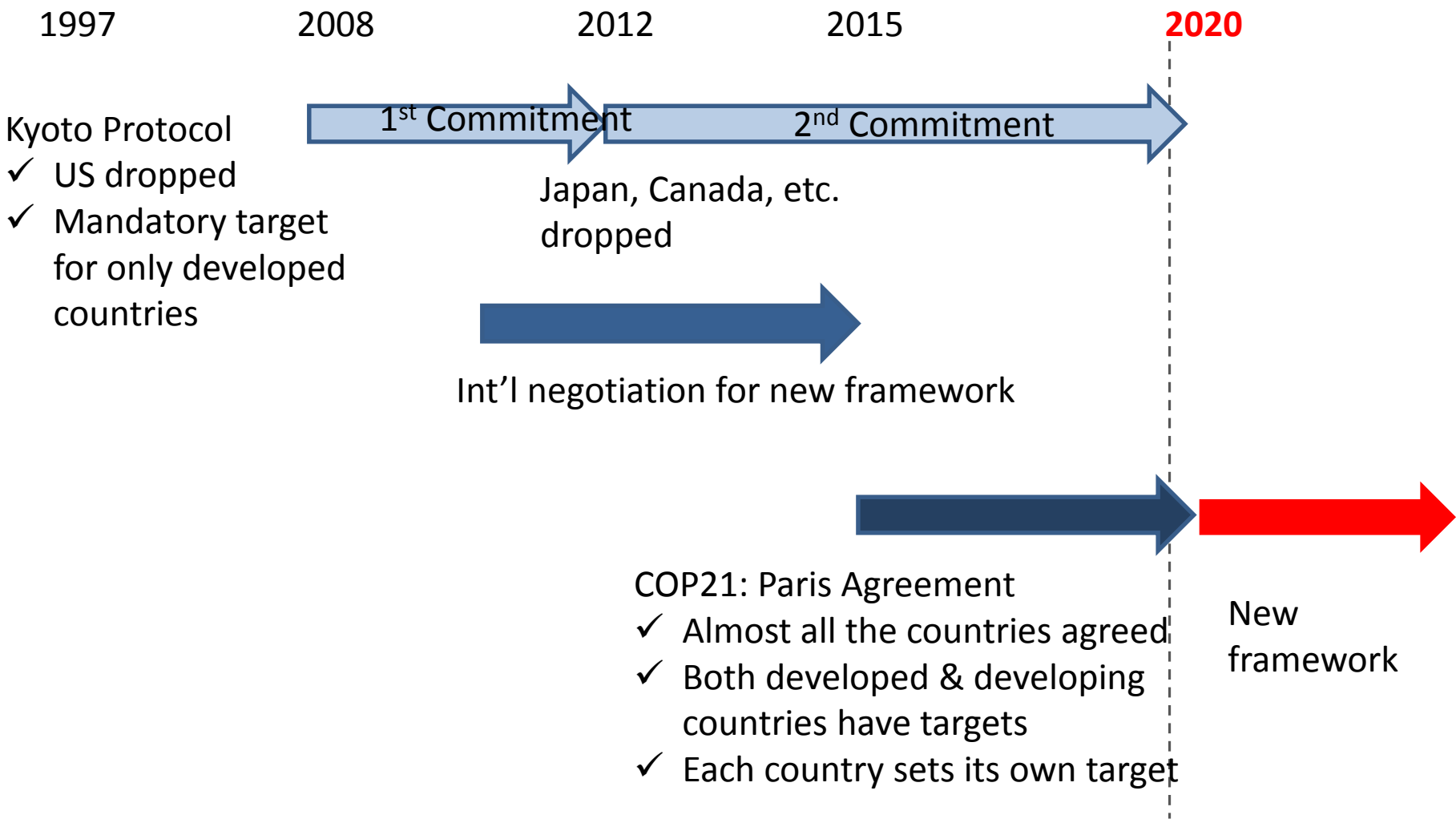
It is good to use more than one measure

Impacts of Emissions Reduction Under Paris Agreement

Aug. 12th 2016

Nozomi Kato
Jiayu Wang

Paris Agreement (agreed Nov. 2015 at COP21)

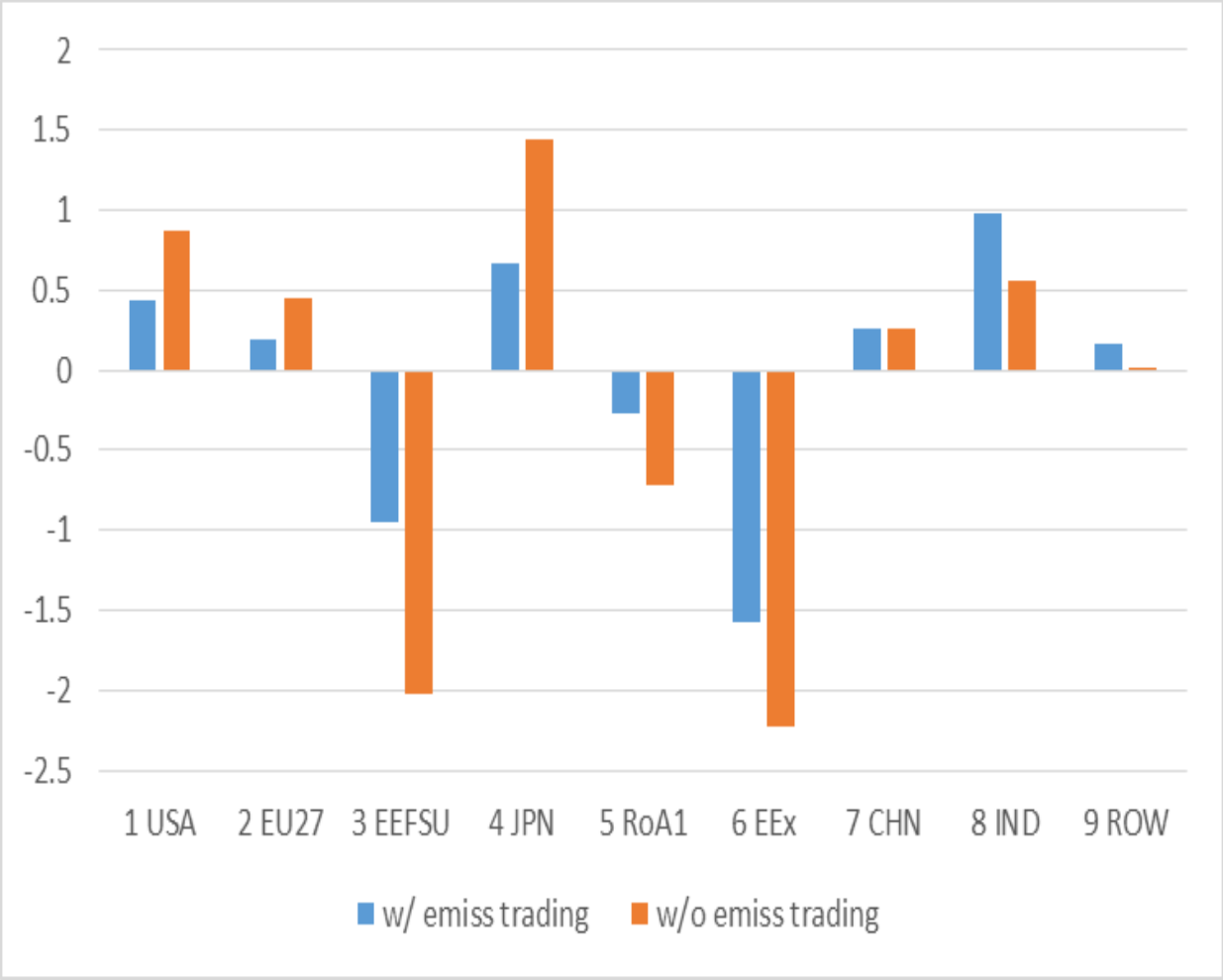


Welfare change under Paris Agreement

($ US million)

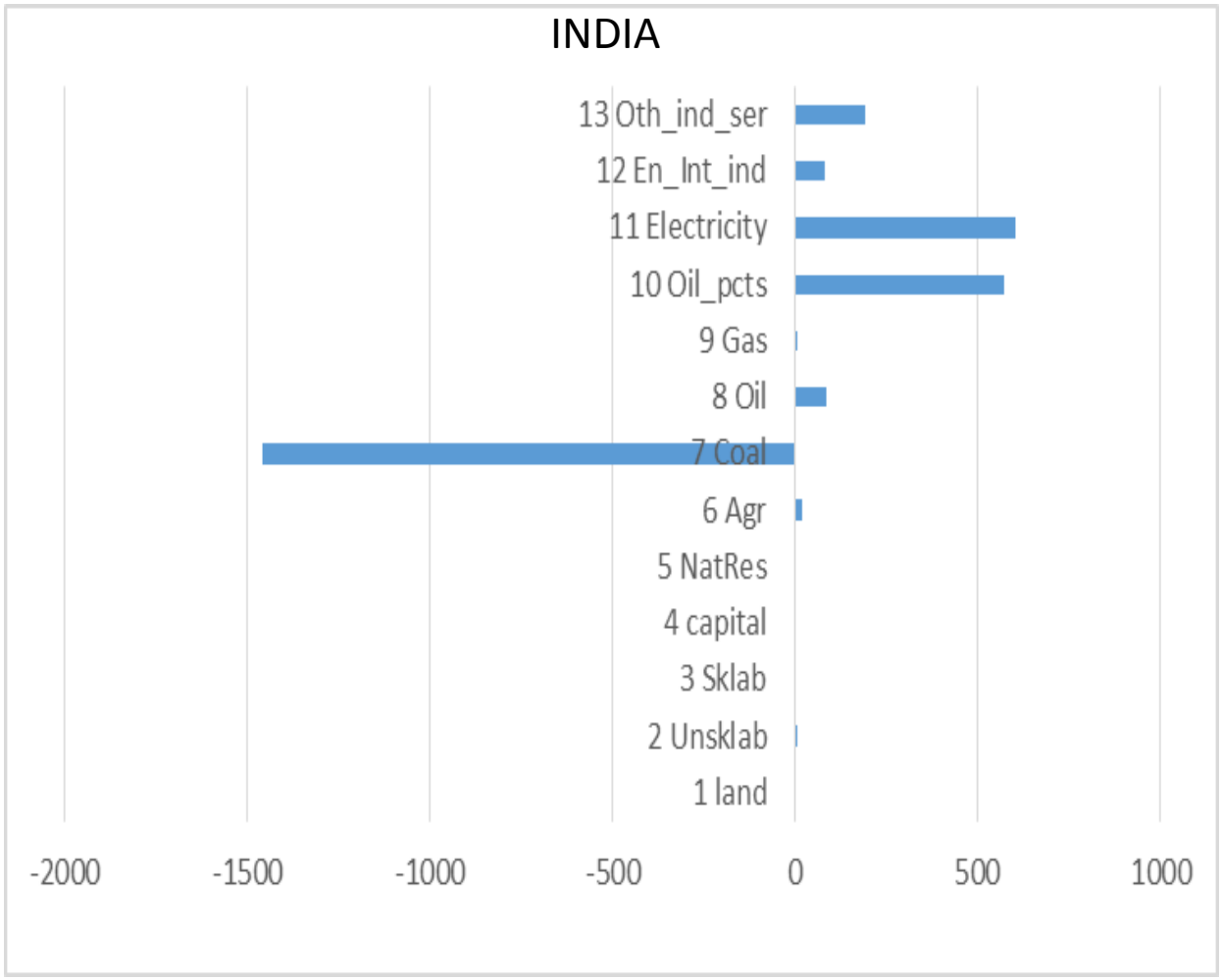
- ✓ EV is composed of CO2 Trading, Allocation efficiency effect, ToT, Investment-Saving
- ✓ Even without emission trading, India gains welfare under Paris Agreement.

ToT % change under Paris Agreement



✓ Energy demand↓, Energy price ↓
✓ Fossil-fuel exporting countries ↓

Allocative Efficiency Effect under Paris Agreement

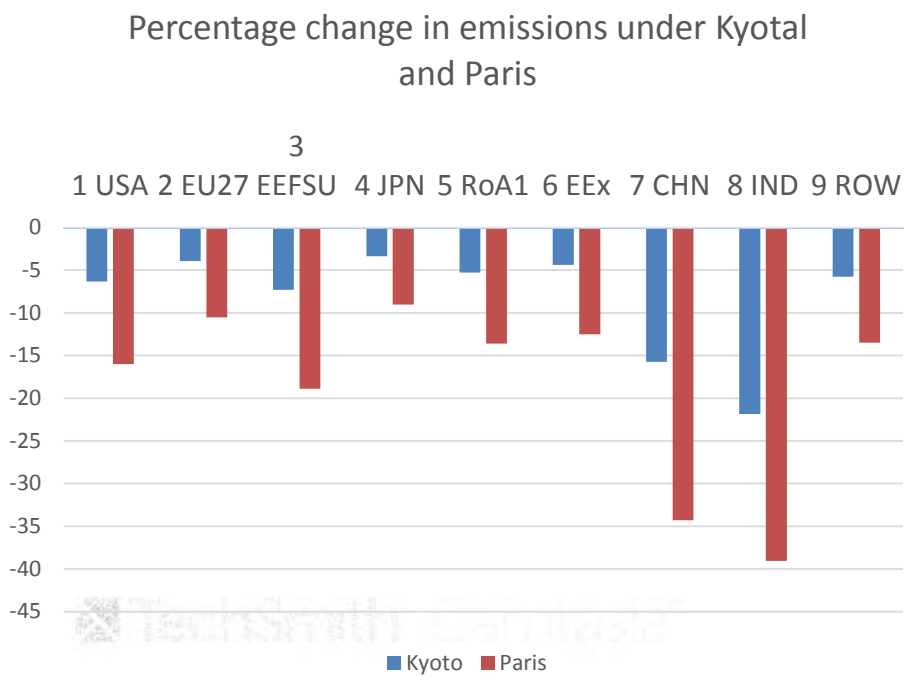


($ US million)

- ✓ India gains welfare by shifting the allocation of intermediates & endowments from Coal to Oil, Gas, Oil products (same results with higher target)
- ✓ That is against India's position 'emission reductions hurts our economy'

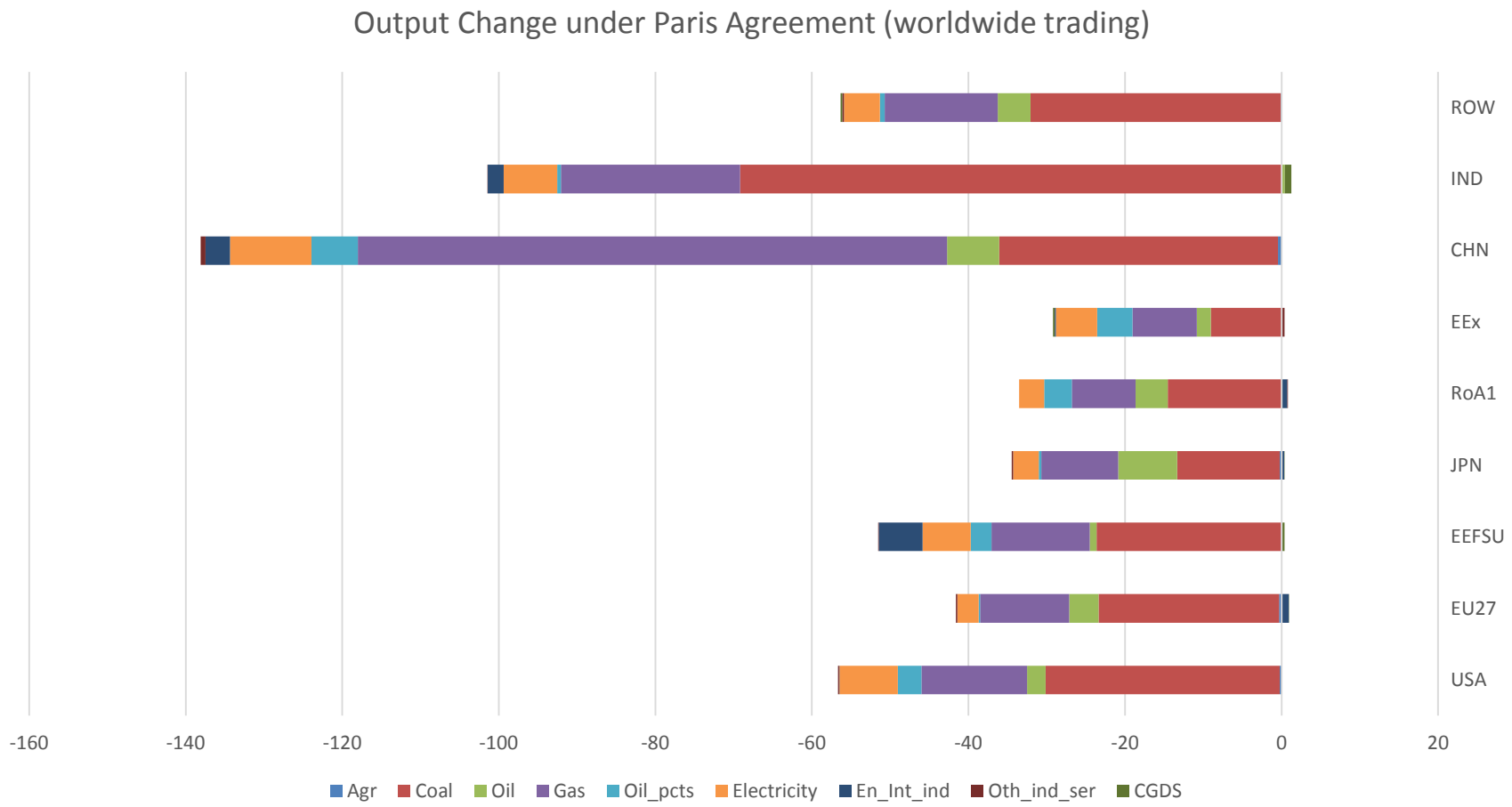
Kyoto Protocol vs Paris Agreement

	Uniform Carbon Tax (2007 USD per tonne)	Emissions Change (% deviation from 2007)
Kyoto	6.7	-8.1
Paris	28.1	-19.3

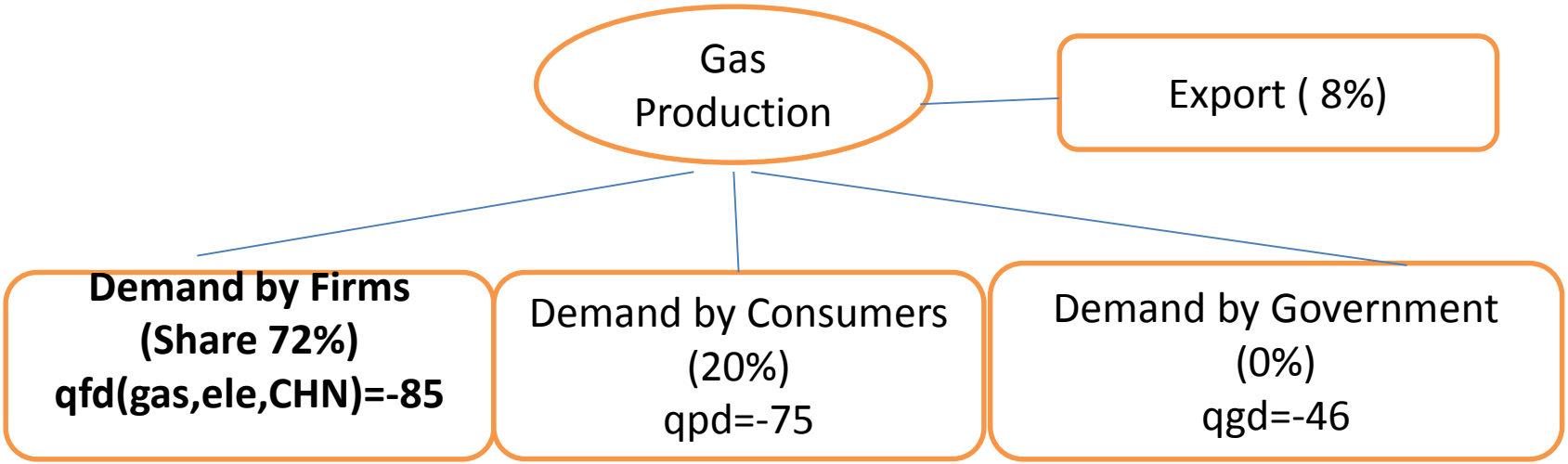


	Kyoto		Paris	
	Welfare	**TOT**	**Welfare**	**TOT**
1 USA	-0.04	0.14	-0.15	0.44
2 EU27	-0.01	0.07	-0.13	0.19
3 EEFSU	-0.06	-0.31	-0.21	-0.94
4 JPN	-0.03	0.20	-0.05	0.67
5 RoA1	-0.17	-0.12	-0.17	-0.27
6 EEx	-0.22	-0.50	**-0.79**	**-1.57**
7 CHN	-0.11	0.12	-0.36	0.25
8 IND	0.21	0.22	0.80	0.99
9 ROW	0.01	0.05	0.02	0.17

An Interesting Question: Why does Gas Production in China Reduce by 75%?



Discover China's Gas Production Change

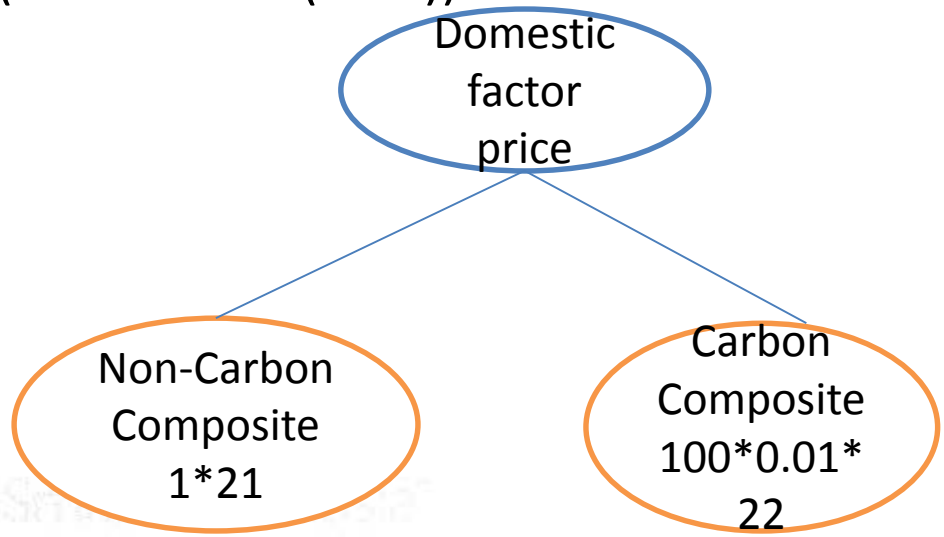


- qfd(gas,ele,CHN) = qft(gas,ele,CHN) - ESUBD(gas) * [pfd(gas,ele,CHN) - pft(gas,ele,CHN)]
- **-85 = -27 - 11 * [54 - 33]**

So China switches to importing gas!

Why does the intermediate use of domestic gas price in electricity increase?

- Because of the CARBON TAX!
- pfd(gas,ele,CHN) = SHVDFANC(gas,ele,CHN) * (pm(gas,CHN) + *tfd*(gas,ele,CHN))+ 100.0 * CO2DFVDFA(gas,ele,CHN) * NCTAXB(REGTOBLOC(CHN))
- SHVDFANC: share of carbon-tax-excl. value of domestic i for use by j in region r
- CO2DFVDFA: emissions intensity of domestic i for use by j in region r
- NCTAXB(REGTOBLOC(CHN)): Nominal carbon tax (22.3 USD)

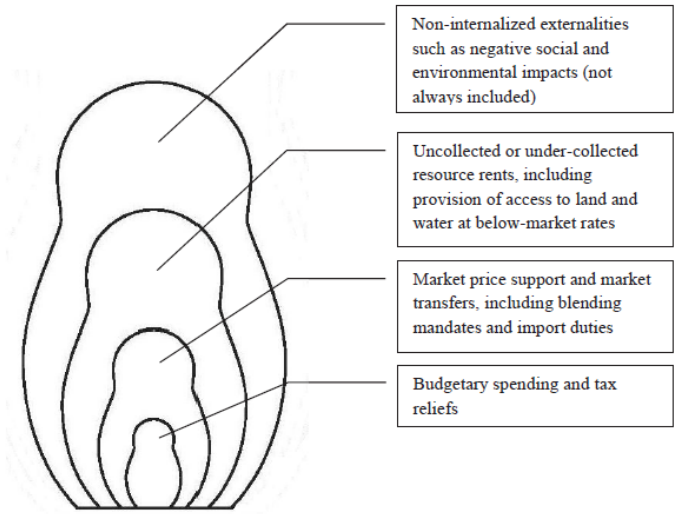


World post tax energy subsidies elimination: a GTAP-E based analysis

Maksym Chepeliev
Moonhee Cho

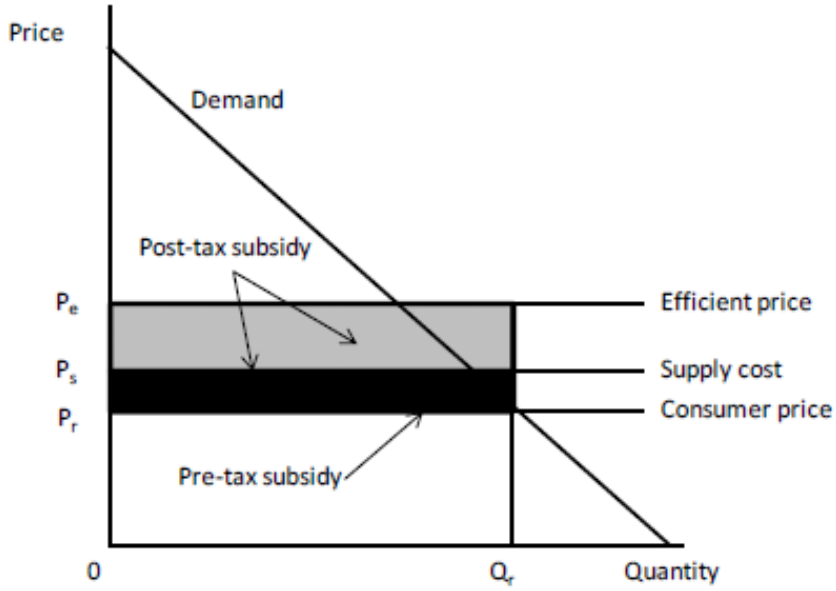
August 12, 2016
West Lafayette, USA

Terms and Definitions



THE "NESTING DOLL" OF SUBSIDY DEFINITIONS

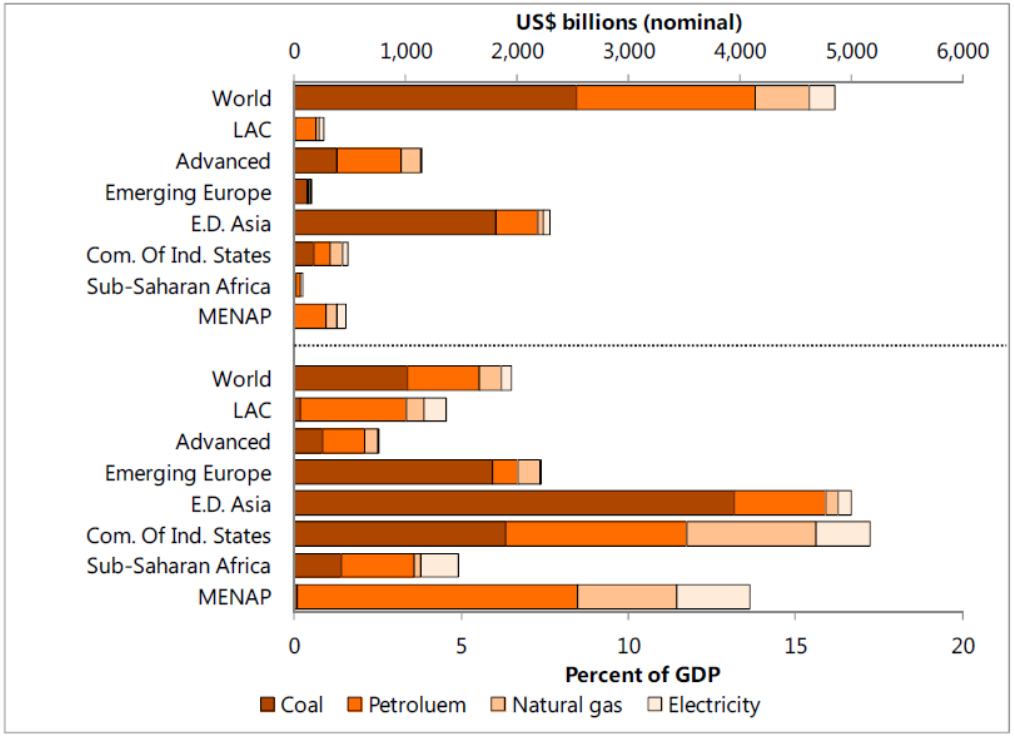
Source: IISD-GSI interpretation using OECD, 2010.



World Energy Subsidies Distribution

Energy Subsidies by Region and Energy Product, 2013

(US$ billions on top axis; percent regional GDP on bottom axis)



Subsidies Representation in GTAP-E

1. Post tax energy subsidies are based on the recent IMF estimates (2013 data).
(Coady D. et al. How large are energy subsidies (2015) IMF Working Paper WP15/105)
2. Regional and commodity mapping to match the GTAP-E model was done.
3. Energy subsidies were rescaled by regions based on the World Bank GDP data.

Estimated corrective taxes on intermediate energy inputs by regions, %

	1 USA	2 EU27	3 EEFSU	4 JPN	5 RoA1	6 EEx	7 CHN	8 IND	9 ROW
2 Coal	259.6	408.9	499.6	300.0	342.4	-	460.5	961.1	739.0
3 Oil	26.1	35.5	20.6	29.2	32.6	83.7	38.3	25.9	29.1
4 Gas	54.1	88.9	76.5	95.3	59.9	215.0	323.4	62.6	96.9
5 Oil_pcts	24.7	18.5	20.3	13.8	23.5	95.7	24.0	27.3	20.7
6 Electricity	9.3	7.8	8.8	6.5	8.8	165.2	10.8	13.0	17.4

Set of experiments

Intermediate energy inputs taxation for all regions

"tfm" and "tfd" shocks

Short term run

- Sluggish capital
- Sluggish labor
- All standard esub values divided by 2

Mid term run

- Mobile labor
- Mobile capital
- Standard esub values

Welfare and trade results

	Short-term Results		Mid-term Results		Short/mid term
	Welfare	TOT	Welfare	TOT	
USA	154 029	8.75	9 160	3.98	
EU27	90 753	2.96	-128 034	1.41	
EEFSU	-105 266	-10.62	-85 275	-4.51	
JPN	78 675	13.54	-4 051	4.97	
RoA1	-66 744	-4.59	-39 651	-1.64	
EEx	-451 846	-18.11	-372 050	-10.37	
CHN	-107 958	-1.3	-117 285	-0.11	
IND	-2 107	6.17	-21 437	4.83	
ROW	-25 416	1.08	-70 351	0.72	

Emissions reduction

	% reduction in emissions							
	Short-term Results				Mid-term Results			
	coal	oil	gas	oil_pcts	coal	oil	gas	oil_pcts
USA	-24.7	-10.4	-6.2	-1.4	-48.5	-23.8	-18.9	-11.7
EU27	-30.6	2.5	-6.8	-5.8	-54.9	-7.3	-20.4	-18.3
EEFSU	-36.4	1.2	-12.5	-8.7	-59.9	-3.6	-25.8	-19.1
JPN	-23.7	12.3	-10.1	-2.7	-47.9	14.7	-28.1	-15.7
RoA1	-27.3	4.5	-5.0	-6.6	-52.3	-0.7	-16.8	-17.2
EEx	-10.5	-19.1	-26.9	-27.6	-18.8	-27.2	-40.9	-40.9
CHN	-37.3	-22.0	-65.6	-16.4	-60.7	-39.3	-78.1	-33.2
IND	-35.8	-11.5	-12.7	-4.6	-68.5	-42.4	-37.0	-15.0
ROW	-37.8	0.6	-14.1	-5.6	-63.7	-5.1	-32.4	-15.6

Output change

Output Increase (%)		Agr	Coal	Oil	Gas	Oil Prod	Electricity	Ener-Inten	Others	CGDS
Short-term	USA	-2.38	-25.47	-11.75	-15.07	1.56	-8.32	-0.76	-0.11	5.06
	EU27	-1.82	-29.88	-14.05	-18.14	-6.66	-6.74	-0.57	-0.42	5.82
	EEFSU	-0.65	-30.63	-7.18	-13.1	-4.02	-11.01	-1.77	-0.73	-10.15
	JPN	-1.75	-30.02	-25.9	-27.46	-1.38	-4.89	-3.5	-0.14	12.52
	RoA1	-0.83	-25.85	-12.51	-6.21	-4.13	-4.55	4.33	-0.2	-3.35
	EEx	-1.34	-6.64	-1.92	-1.78	-31.94	-40.9	-10.85	-3.62	-46.28
	CHN	-1.71	-35.65	-24.96	-94.15	-21.25	-16.44	-4.05	-2.21	-11.01
	IND	-0.86	-30.59	-12.22	-13.79	-0.25	-17.77	-5.92	-1.38	-5.39
	ROW	-0.64	-28.96	-20.22	-19.02	-1.5	-13.93	-1.23	-0.55	-1.4
Mid-term	USA	-2.91	-48.82	-27.09	-30.35	-4.51	-16.65	1.68	-0.71	3
	EU27	-2.99	-52.87	-38.42	-54.77	-20.11	-9.87	1.13	-1.48	3.75
	EEFSU	-0.81	-47.59	-17.53	-24.06	-12.59	-18.99	-14.02	-0.71	-5.92
	JPN	-2.67	-50.91	-50.76	-72.38	-13.03	-10.8	-4.4	-1.1	5.84
	RoA1	-1.57	-53.41	-35.98	-17.42	-14.72	-5.48	12	-0.4	0.07
	EEx	-1.63	-21.36	-8.14	-6.99	-54.29	-58.88	-24.3	-3.31	-28.08
	CHN	-2.99	-57.8	-51.75	-99.9	-40.81	-22.9	-6.9	-3.99	-7.33
	IND	-1.96	-64.36	-29.53	-48.4	-7.84	-29.35	-13.02	-2.92	-5.57
	ROW	-0.92	-53.11	-39.43	-57.46	-8.93	-25.41	-2.97	-1.4	-1.19

Trade balance

Trade Balance		Agr	Coal	Oil	Gas	Oil Prod	Electricity	Ener-Inten	Others	Total
Short-term	USA	-5 109	-1 132	50 286	-5 940	6 929	-559	-8 630	-239 675	*-203 831*
	EU27	-7 326	6 077	81 212	13 889	-7 510	621	6 253	-310 410	*-217 192*
	EEFSU	1 470	-2 696	-54 972	-11 491	8 456	543	7 342	74 420	*23 073*
	JPN	-1 965	4 446	29 443	6 430	-858	0	-9 962	-145 423	*-117 890*
	RoA1	-806	-8 155	-22 870	-10 094	1 929	1 124	22 551	35 987	*19 666*
	EEx	11 218	-5 346	-131 902	5 666	-9 875	-341	1 346	435 539	*306 305*
	CHN	2 616	-649	31 077	-3 654	-7 372	-331	-18 906	134 367	*137 148*
	IND	-489	2 195	15 493	559	3 189	-211	-8 304	11 173	*23 605*
	ROW	-1 832	6 630	372	3 743	6 020	-847	2 027	13 002	*29 116*
Mid-term	USA	-5 768	-1 498	24 031	-12 251	33 612	-785	27 176	-198 879	*-134 363*
	EU27	-9 663	7 555	78 909	3 619	-10 594	3 126	62 526	-290 419	*-154 941*
	EEFSU	1 644	-2 937	-54 635	-8 254	16 244	-9	-19 143	80 823	*13 733*
	JPN	-2 116	4 974	27 805	7 191	3 053	0	-9 558	-85 704	*-54 354*
	RoA1	-1 078	-10 370	-35 814	-9 273	2 624	1 669	50 924	242	*-1 077*
	EEx	11 028	-5 070	-56 871	25 996	-56 388	-1 075	-73 264	360 422	*204 778*
	CHN	3 441	-477	32 536	-2 999	-16 359	-493	-22 760	91 590	*84 479*
	IND	96	2 518	11 528	-223	8 476	-320	-18 402	15 962	*19 636*
	ROW	486	8 015	-26 621	-4 302	22 881	-2 113	-789	24 550	*22 108*

Thank you!