

Structural changes in embodied CO₂ trade due to US withdrawal from Paris Agreement: Fusion of CGE and IO analysis



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1. Introduction

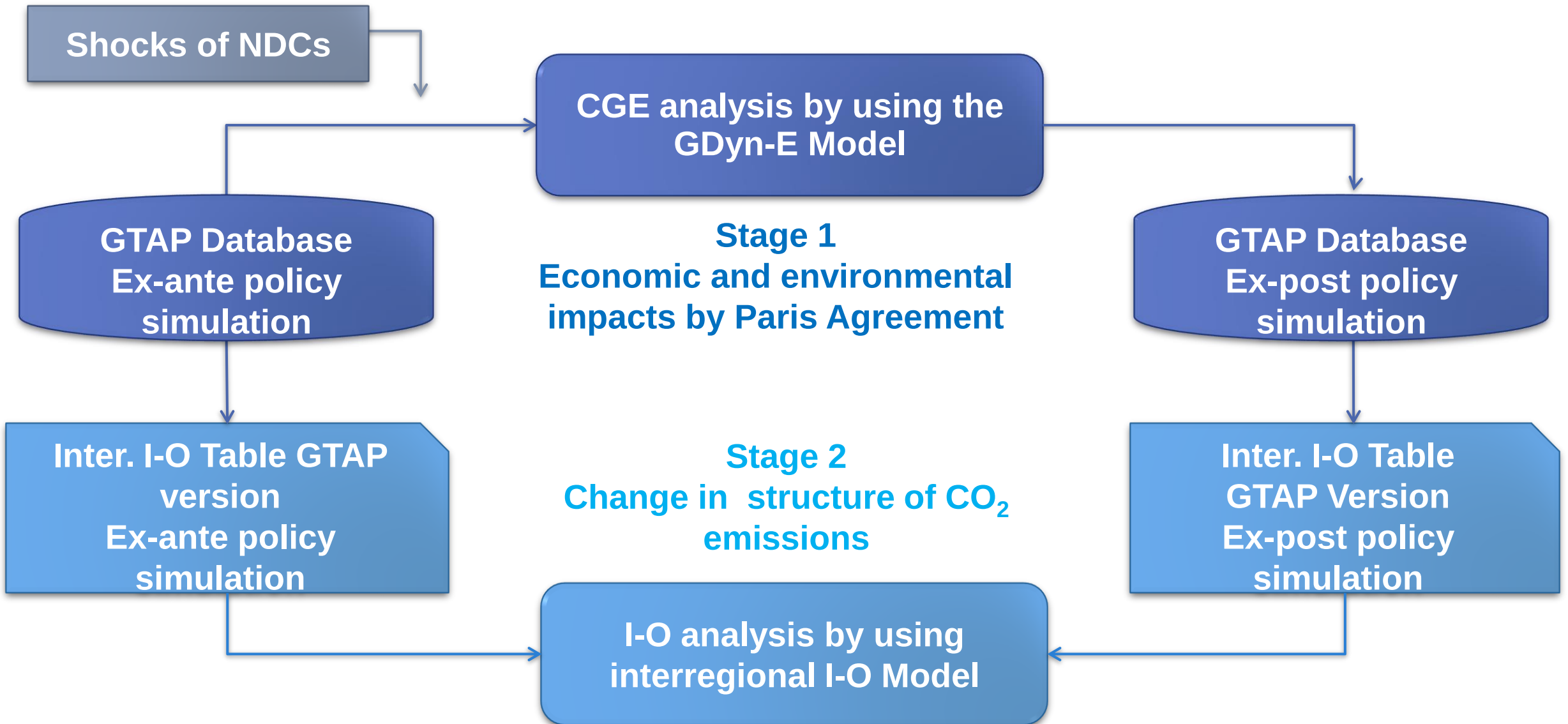
1-1. Background

- The Paris Agreement to limit global warming was adopted on December 12, 2015 and came into force on November 4, 2016.
 - The comprehensive national climate action plans: NDCs
 - Including developed and developing countries
- The Trump administration has formally notified the United Nations that it will withdraw the US from the Paris Agreement.

1-2. Research Objectives

- Structural changes in CO₂ emissions due to the US withdrawal from the Paris Agreement
- Carbon pricing policy simulations based on NDCs of major countries both with and without the US
- Analyzing structural changes in CO₂ emissions will give us more information for effective carbon reduction policy.

1-3. Methodology



2. CGE Analysis: The GDyn-E Model

2-1. The GDyn-E model

- Golub, A.(2013) Analysis of climate policies with Gdyn-E, GTAP Technical Paper 32
- The Gdyn-E model combines the GDyn model with the GTAP-E model
- Economic linkages between energy and the environment
- Capital accumulation and international capital movement
- Distinguishes between asset location and ownership

2-2. Region and Sector Aggregation

■ **GTAP Database Ver.10**, 2014, 141 countries/regions, 65 sectors

■ **23regions**

Oceania, China, Japan, Korea, Taiwan, Indonesia, Malaysia, Singapore, Thailand, Vietnam, Rest of ASEAN, India, Rest of Asia, Canada, US, Mexico, Latin America, EU, Rest of Europe, Russia, Turkestan, the Middle East and North Africa(MENA), Sub-Saharan Africa (SSA)

■ **28sectors**

Agriculture, Livestock, Forestry, Fishing, Coal mining, Crude oil, Gas & distribution, Petroleum & coal products, Electricity, Other mining, Processed food, Textiles & clothing, Paper & publishing, Chemical products, Nonmetallic minerals, Iron, Automobile & parts, Transportation equipment, Electronics equipment, Machine equipment, Other manufactures, Water, Construction, Trade, Water transport services, Air transport services, Other transport services, Other services

2-3. Simulation Scenarios

■Baseline

- Based on Chappuis and Walmsley (2011) Projections for World CGE Model baseline, GTAP Research Memorandum, 22.

■Sim 1

- The Paris Agreement scenario
- Implementation of NDCs of Oceania, China, Japan, Korea, Taiwan, Indonesia, Malaysia, Singapore, Thailand, Vietnam, Canada, US, Mexico, EU, Russia

■Sim2

- US withdrawal scenario

Table 1 NDCs and corresponding Target for CO₂ growth rate

	NDCs (unconditional target)	Target CO ₂ growth rates (%)
Oceania	Australia: 26%–28% reduction by 2030 compared with 2005; New Zealand: 30% reduction by 2030 compared with 2005	–4.14
China	Peaking of CO ₂ emissions around 2030	
Japan	26% reduction by 2030 compared with 2013	–1.51
Korea	37% reduction by 2030 compared with BAU	–2.50
Taiwan	20% reduction by 2030 compared with 2005	–2.88
Indonesia	29% reduction by 2030 compared with BAU	2.06
Malaysia	35% reduction of emissions intensity (CO ₂ /GDP) by 2030 compared with 2005	1.59
Singapore	36% reduction of emissions intensity (CO ₂ /GDP) by 2030 compared with 2005	–1.99

Table 1 NDCs and corresponding targets for CO₂ growth rate
(continued)

	NDCs (unconditional target)	Target CO ₂ growth rates (%)
Thailand	20% reduction by 2030 compared with BAU	2.08
Vietnam	8% reduction by 2030 compared with BAU	3.12
Canada	30% reduction by 2030 compared with 2005	−4.83
US	26%–28% reduction by 2025 compared with 2005	−4.39
Mexico	25% reduction by 2030 compared with BAU	0.04
EU	40% reduction by 2030 compared with 1990	−3.41
Russia	25%–30% reduction by 2030 compared with 1990	−1.29

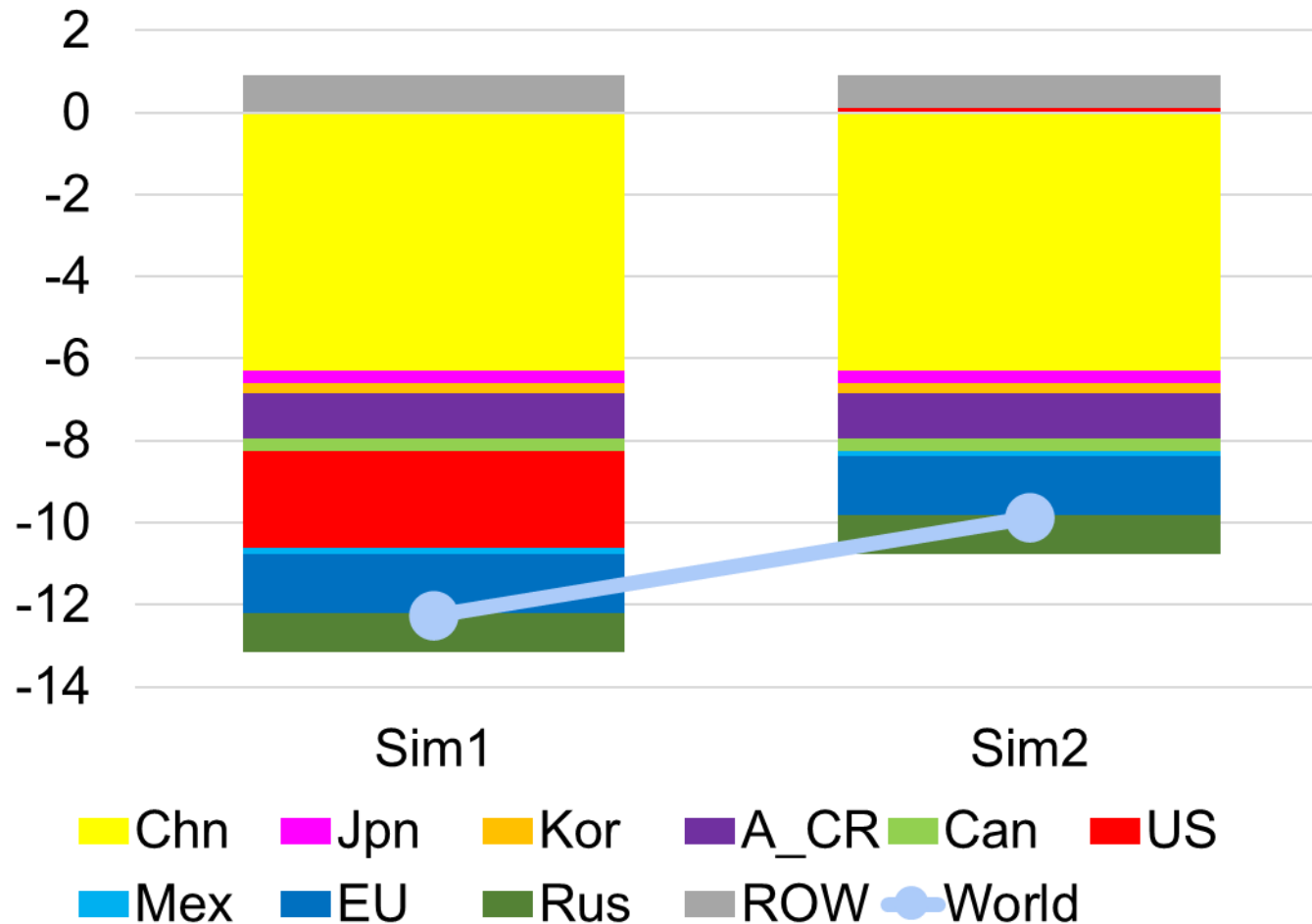
China's target CO ₂ growth rate											
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Baseline	7.29	7.15	6.96	6.79	6.63	6.58	6.41	6.23	6.05	5.88	5.82
C-NDC	6.62	5.96	5.30	4.64	3.97	3.31	2.65	1.99	1.32	0.66	0

2-4. Macro Impacts

Table 2 Macro impacts in 2030 (Differences from the baseline)

	Sim1(Paris Agreement scenario)					Sim2 (US withdrawal scenario)				
	GDP %	EV Billion \$	Terms of trade %	Carbon price of CO2 (\$/ton)	CO2 %	GDP %	EV Billion \$	Terms of trade %	Carbon price of CO2 (\$/ton)	CO2 %
Oce	-1.6	-32.9	0.4	189.5	-44.4	-1.8	-41.4	-0.7	183.8	-44.4
Chn	-0.1	-201.0	0.1	29.1	-28.8	-0.3	-212.2	0.0	28.4	-28.8
Jpn	-1.0	-35.4	2.3	164.6	-26.8	-1.3	-39.9	2.1	159.4	-26.8
Kor	-2.6	-17.0	2.2	179.8	-37.0	-2.8	-18.1	2.1	175.0	-37.0
Idn	-1.4	-15.3	-1.5	82.5	-29.0	-1.6	-18.8	-1.8	80.2	-29.0
Can	-2.9	-63.1	-2.7	217.3	-48.6	-2.9	-54.0	-1.5	205.9	-48.6
US	-1.2	-247.9	0.1	145.1	-46.8	0.6	6.0	0.2	0.0	2.5
Mex	-0.6	-10.7	-1.1	82.6	-22.0	-0.5	-2.9	-0.3	78.4	-22.0
EU	-2.2	-240.3	1.7	305.5	-41.1	-2.4	-272.0	1.4	295.6	-41.1
Rus	-8.2	-172.9	-6.9	146.8	-40.9	-8.3	-165.2	-6.0	145.1	-40.9

Figure 1 Impact on CO₂ emissions in 2030
(Differences from the baseline, Billion tons)



■ CO₂ emissions in the world for Sim2

increase by about 2.4 billion tons compared to Sim 1

■ CO₂ emissions in the US for Sim2

increase by about 2.5 billion tons compared to Sim1.

2-5. Sectorial Impacts

- Production decline in service, petroleum & coal products and non mineral products sector
- Total CO₂ emissions remain almost unchanged.

Figure 2 Impact on China's output and CO₂ in 2030
(Differences from the baseline)

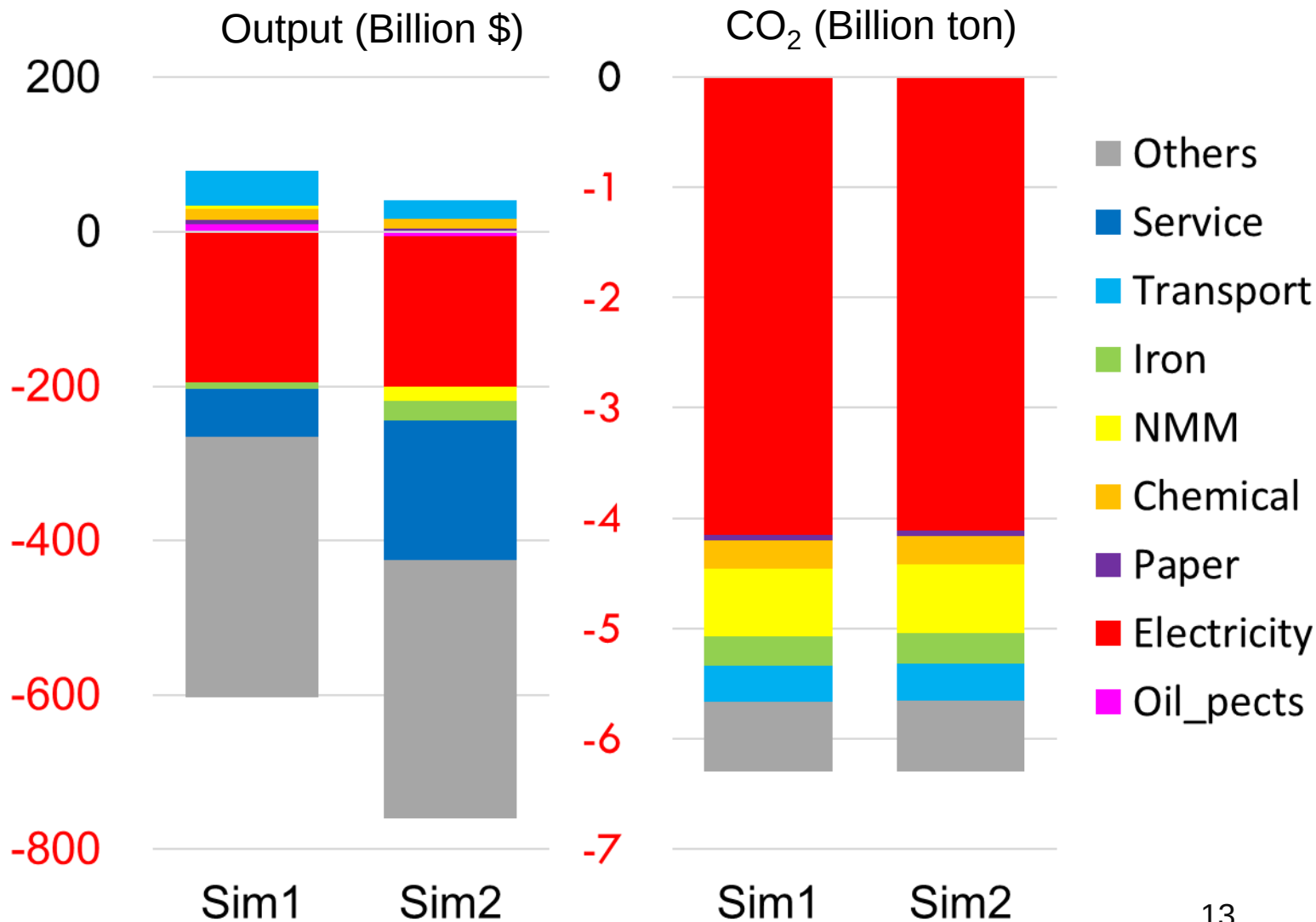


Figure 3 Impact on Japan's output and CO₂ in 2030
(Differences from the baseline)

- Production decline in service
- Total CO₂ emissions remain almost unchanged.

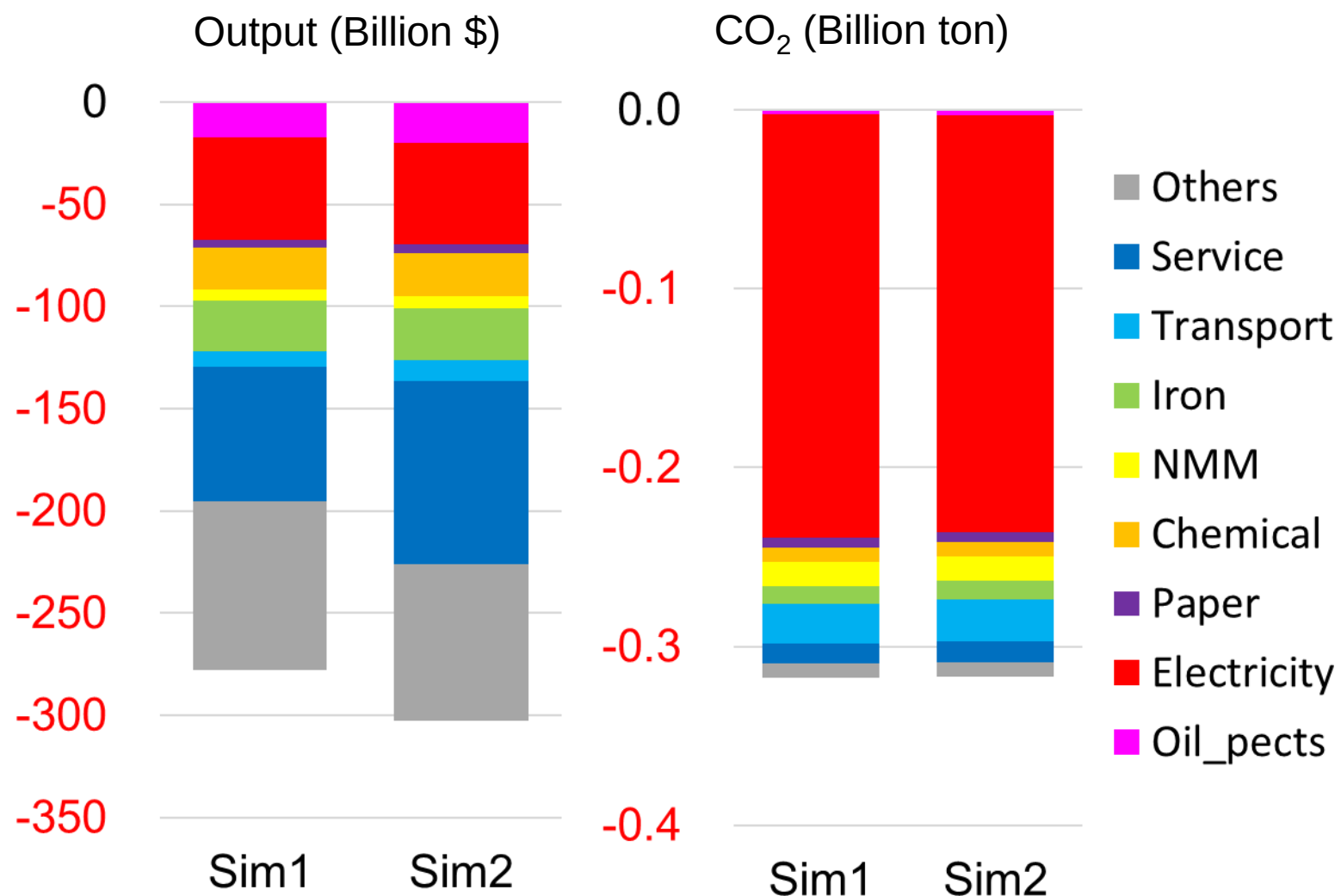
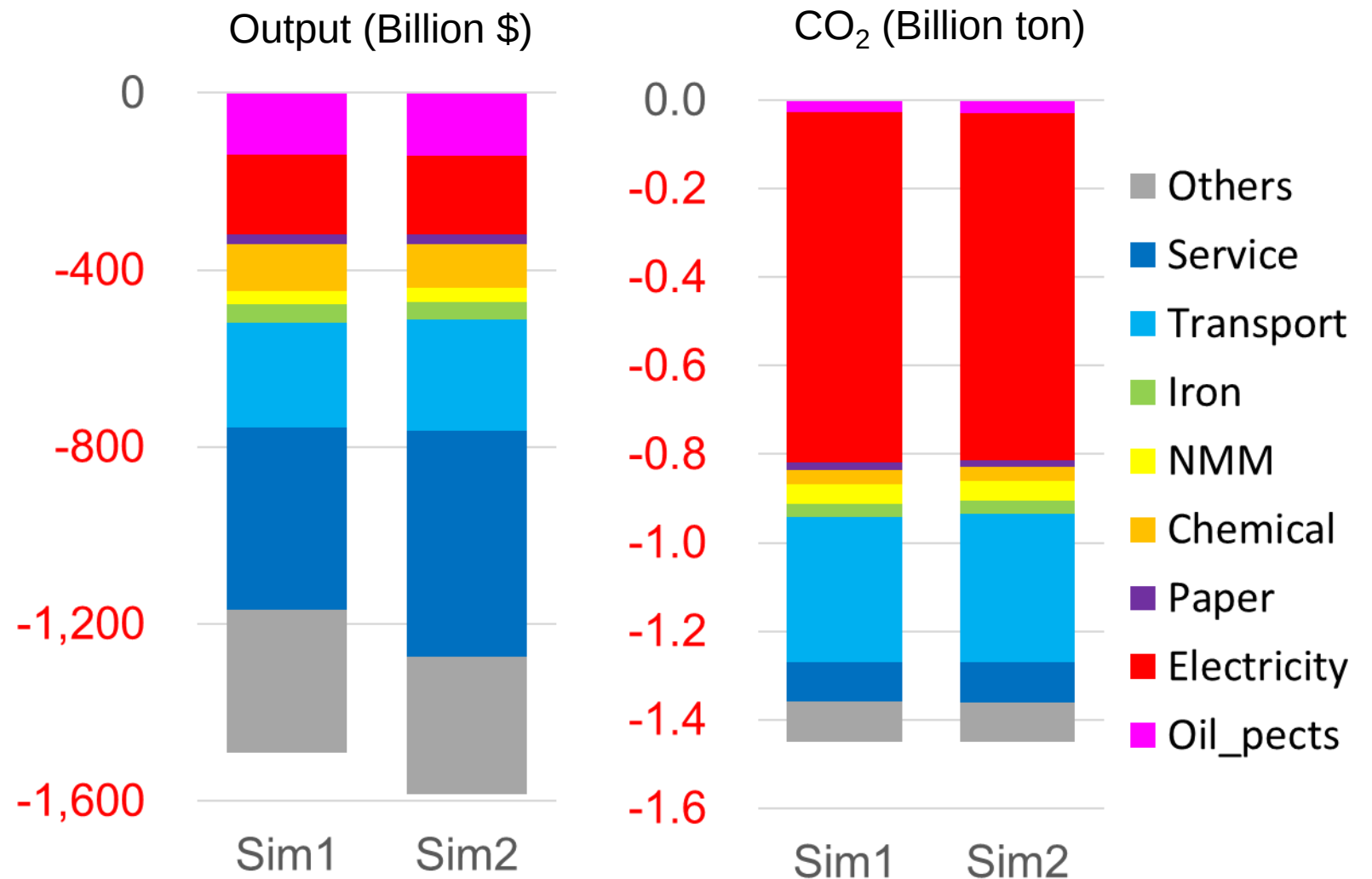


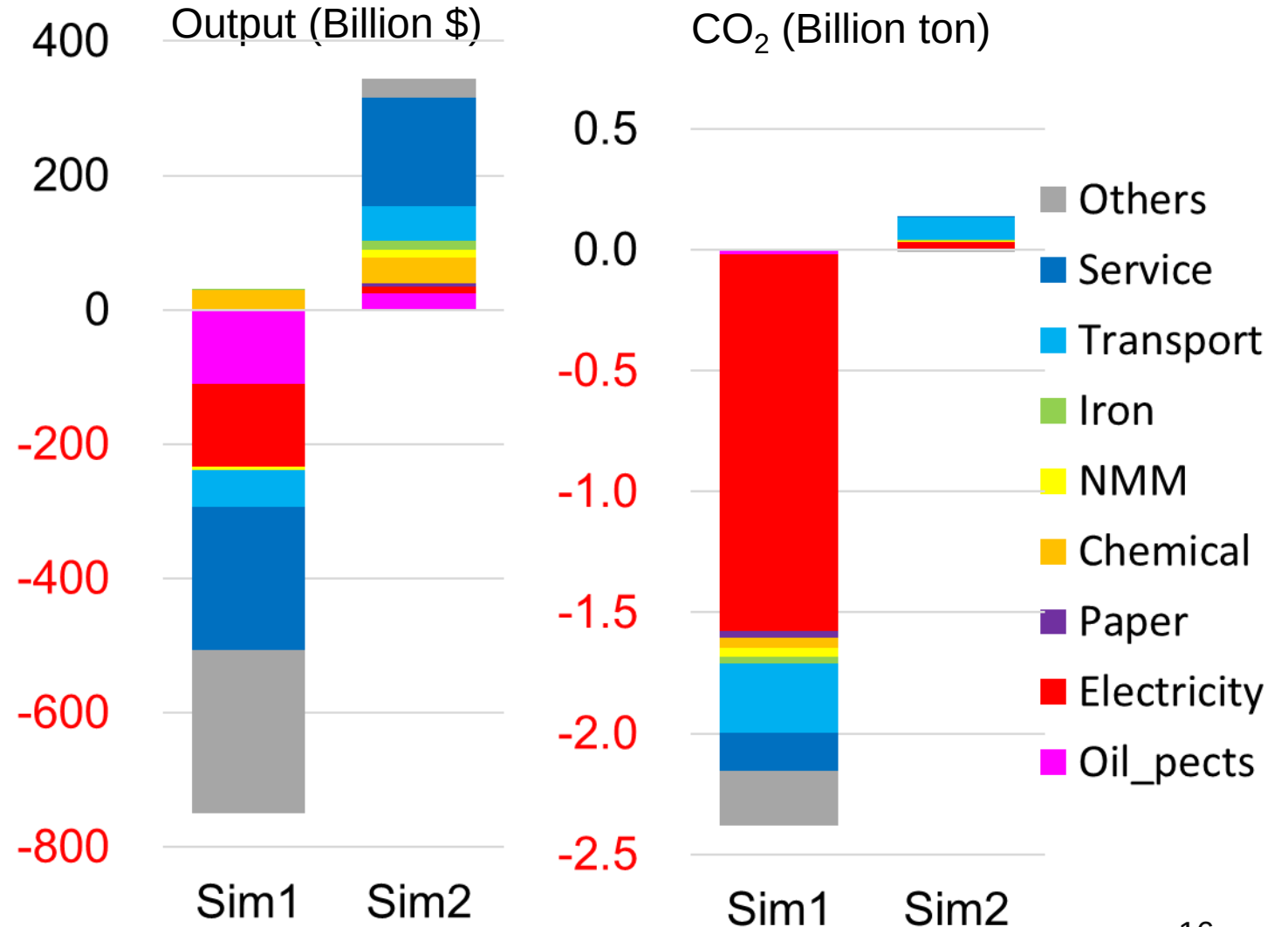
Figure 4 Impact on the EU's output and CO₂ in 2030
(Differences from the baseline)

- Production decline in service
- Total CO₂ emissions remain almost unchanged.



- Output of many industries exceeds the baseline for Sim2. service and transport
- CO₂ emissions in service, transport chemical, and petroleum & coal products exceed the baseline for Sim2.

Figure 5 Impact on the US's output and CO₂ in 2030
(Differences from the baseline)



3. Input-Output Analysis

3-1. Input-Output model

Leontief inverse

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{f} \quad (1)$$

Output Final demand

$\mathbf{x}$: *vector of industry gross outputs*

$\mathbf{A}$: *matrix of input coefficients*

$\mathbf{f}$: *vector of final demands*

■ CO₂ emissions embodied in trade

- Consumption-based CO₂ emissions
- Production-based CO₂ emissions
- CO₂ exports
- CO₂ imports

■ Structural decomposition

- CO₂ output ratio change contribution
- Technology change contribution
- Final demand change contribution

3-2. Interregional IO table

- We follow the proportional procedure in Bems et al. (2010, 2011) and in Johnson and Noguera (2012). We assume that the share of imported goods i from country s in total imported goods i is the same across both industries and final demand.
- Four IO tables
 - Ex-ante policy simulation(Baseline), IO table 2020
 - Ex-ante policy simulation (Baseline), real IO table 2030, at 2020 base price
 - Ex-post policy simulation (Sim1), real IO table 2030, at 2020 base price
 - Ex-post policy simulation (Sim2), real IO table 2030, at 2020 base price

3-3. CO₂ emissions embodied in trade

Table 3 CO₂ Emissions embodied in trade (Baseline,2030, Million tons)

	Chn	Jpn	Kor	A_NDC	Can	US	Mex	EU	Rus	ROW	P_based
Chn	17,183	283	108	637	101	738	128	915	174	1,653	21,919
Jpn	71	873	7	38	3	29	4	34	6	53	1,119
Kor	75	13	328	31	3	28	5	37	7	67	595
A_NDC	280	69	24	2,189	16	116	13	170	18	277	3,172
Can	25	7	3	11	303	144	7	33	3	54	590
US	119	31	17	62	66	4,086	62	168	15	226	4,852
Mex	13	3	1	6	9	93	352	17	1	40	536
EU	143	36	15	81	22	133	13	2,508	47	410	3,408
Rus	59	17	9	30	4	39	4	143	1,794	184	2,284
ROW	556	125	60	279	50	387	40	856	114	12,394	14,861
C_based	18,525	1,455	573	3,365	577	5,793	628	4,881	2,180	15,358	53,334

Note: A_NDC is Asian countries with carbon constrains (Oceania, Taiwan, Indonesia, Malaysia, Singapore, Thailand, Vietnam)

Table 4 CO₂ Emissions embodied in trade (Sim1,2030, Million tons)

	Chn	Jpn	Kor	A_NDC	Can	US	Mex	EU	Rus	ROW	P_based
Chn	12,188	206	77	452	67	521	92	666	104	1,252	15,623
Jpn	51	622	5	27	2	21	3	26	4	41	801
Kor	46	8	194	20	2	17	3	25	4	45	365
A_NDC	174	46	15	1,404	11	80	9	121	11	196	2,066
Can	13	4	1	6	143	75	4	17	1	31	296
US	69	19	10	37	35	2,010	35	104	8	145	2,472
Mex	10	2	1	4	6	65	274	13	1	30	405
EU	87	23	10	49	12	79	8	1,424	24	244	1,959
Rus	42	12	6	18	3	27	2	90	1,013	119	1,332
ROW	597	116	58	296	55	454	44	946	110	13,080	15,755
C_based	13,276	1,058	376	2,312	336	3,349	473	3,432	1,279	15,182	41,073

■ Comparing with the baseline, CO₂ emissions based on both consumption and production decrease in carbon restricted countries. Production based CO₂ emissions in countries without carbon restriction increase.

Table 5 CO₂ Emissions embodied in trade (Sim2,2030, Million tons)

	Chn	Jpn	Kor	A_NDC	Can	US	Mex	EU	Rus	ROW	P_based
Chn	12,160	205	77	451	69	556	95	662	105	1,247	15,625
Jpn	51	622	5	27	2	22	3	26	4	41	802
Kor	46	8	194	20	2	18	3	25	4	45	365
A_NDC	174	46	15	1,407	11	81	9	119	11	195	2,068
Can	13	3	1	5	144	76	4	17	1	30	295
US	121	33	18	64	67	4,178	61	182	14	241	4,977
Mex	9	2	1	4	6	67	276	12	1	28	405
EU	86	22	9	49	12	79	8	1,424	25	243	1,958
Rus	41	12	6	18	3	27	2	89	1,016	117	1,331
ROW	589	114	57	292	55	430	45	932	110	13,006	15,632
C_based	13,290	1,068	383	2,335	371	5,534	506	3,487	1,290	15,193	43,458

■ Comparing with the baseline, CO₂ emissions based on both consumption and production decrease in carbon restricted countries. Production based CO₂ emissions in countries without carbon restriction increase.

Impacts of the US withdrawal on consumption-based CO₂ emissions

- The world's CO₂ emissions in Sim2 increase by about 2.4 billion tons compared to Sim1.
- The US consumption-based CO₂ increase is about 2.2 billion tons, and that of countries other than the US is about 0.2 billion tons. Therefore, about 8.3% of the increase in CO₂ caused by the US withdrawal is due to the increase in consumption-based CO₂ emissions in countries other than the US.

3-4. Structural Decomposition

Table 6 Structural decomposition of CO₂ emissions from 2020 to 2030, baseline (million tons)

	CO ₂ / output	Technolo gy	final demand	Total
Chn	-563	-91	11,649	10,995
Jpn	19	-493	641	167
Kor	9	-690	778	97
A_NDC	16	-1,041	2,163	1,138
Can	-14	-330	397	53
US	-88	-1,397	2,015	530
Mex	-19	1	152	134
EU	31	-3,425	3,915	521
Rus	51	-175	884	760
ROW	-105	-1,235	7,565	6,224
World	-662	-8,876	30,157	20,619

■ The main cause of the increase in CO₂ emissions is the final demand change contribution, which greatly exceeds the minus technology change.

Table 7 Structural decomposition of the differences in CO₂ emissions from the baseline caused by Sim1 (2030, million tons)

	CO ₂ / output	Technolo gy	final demand	Total
Chn	-4,715	-1,227	-354	-6,296
Jpn	-202	-71	-44	-317
Kor	-128	-73	-29	-230
A_NDC	-645	-304	-158	-1,106
Can	-225	-39	-30	-293
US	-1,797	-288	-295	-2,380
Mex	-92	-30	-9	-131
EU	-986	-273	-190	-1,449
Rus	-367	-284	-301	-952
ROW	147	375	371	894
World	-9,010	-2,213	-1,039	-12,261

Table 8 Structural decomposition of the differences in CO₂ emissions from the baseline caused by Sim2 (2030, million tons)

	CO ₂ / output	Technolo gy	Final demand	Total
Chn	-4,678	-1,200	-416	-6,294
Jpn	-201	-69	-47	-317
Kor	-127	-73	-30	-230
A_NDC	-638	-301	-165	-1,104
Can	-220	-48	-27	-295
US	3	66	56	125
Mex	-90	-34	-6	-131
EU	-978	-274	-198	-1,450
Rus	-364	-288	-301	-952
ROW	135	332	305	771
World	-7,157	-1,890	-829	-9,876

■ Improvement of CO₂ output ratio contributes most to carbon reduction. However, the US withdrawal diminishes this contribution in carbon-restricted countries.

4. Concluding Remarks

- With the US departure from the Paris Agreement, the world's CO₂ emissions increase by about 2.4 billion tons compared to the case without the US departure.
- This is due to an increase in CO₂ emitted in the US.
- However, our I-O analysis reveals that about 8.3% of the increase in CO₂ is due to the increase in consumption-based CO₂ emissions in countries other than the US.
- In other words, if a large country like the US leaves the agreement, it will undermine the effectiveness of carbon reduction policies by increasing CO₂ imports of other countries. It is important that carbon constraints cover the entire world.