GLOBAL CLIMATE CHANGE: STRATEGIC INCENTIVES

Study Case: Renewable Productivity & Global Abatement Equilibria

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- This presentation is based on joint paper with **Prof Rod Tyers of** University of Western Australia and Research School of Economics, The Australian National University.
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I. OVERVIEW/ BACKGROUND

- Global Warming Gridlock highlights the importance of evaluating strategic interactions on global mitigation policy:
- Latest prominent literature of Nordhaus (2015) with Coalition-DICE (C-DICE) model reveals that potential climate club with uniform carbon pricing will lead to non cooperative equilibrium with minimal abatement.
- Sælen (2016), Hovi et al. (2017) finds that transfer payment is potential and important initiation of large emitters

I. OVERVIEW/ WHAT HAVE BEEN DONE IN THE LATEST WORK?

New Integrated Assessment Model to re-examine Nordhaus' finding by capturing all the relevant dynamics and regional interactions:

- ***Estimating Mitigation Cost***: Adaptation of GDyn-Energy Model (Golub 2013). Three Energy commodities: Coal, Oil and Gas.
- ***Estimating Regional Climate Benefits***: Meta-analysis that links carbon concentration with region specific measures of economic welfare;
- ***Strategic Interactions***: Multiplayer Games Nash Equilibrium and PV Analysis of affordability of side payment.

I. OVERVIEW/ SUMMARY OF PREVIOUS FINDING

- In present value terms the **US and China** would derive positive net economic gains from their unilateral implementation of the tax. This finding contradicts the analysis using the DICE-Coalition model by Nordhaus (2015);
- The large carbon-emitting regions**, the US, the EU, and China**, have sufficient individual effects on the global climate. It also highlights the crucial role of China in global climate policy;
- It does confirm the "small paradox" theory of Barrett (1994; 2003). Transfer payment is affordable yet politically difficult.

I. OVERVIEW/ BACKGROUND

Things to be Improved:

- The original adaptation does not include the renewable energy.
- How the different in renewable productivity rate could change the strategic behaviour of large players? .

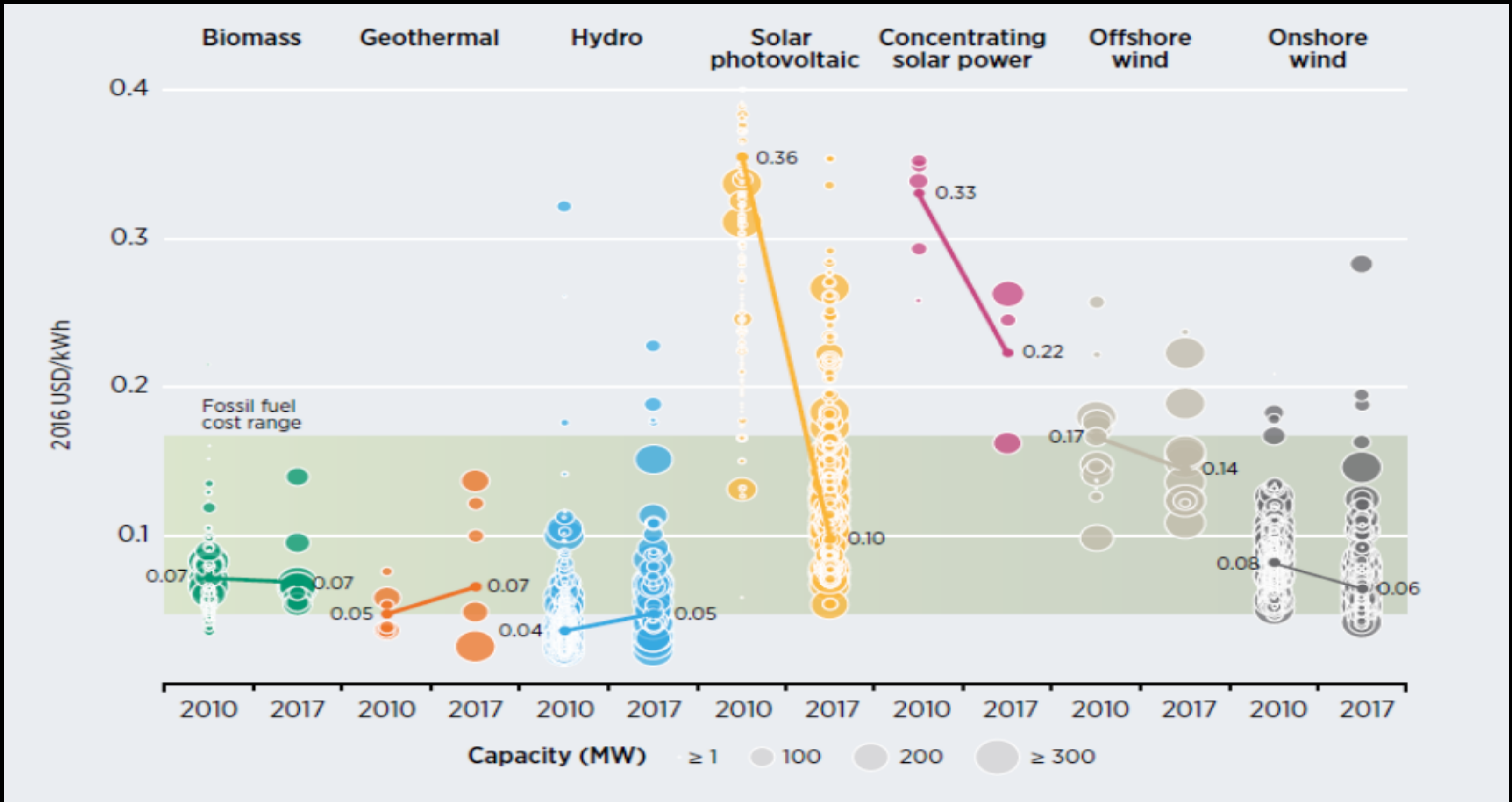
I. OVERVIEW/ BACKGROUND

Renewable Energy is Growing!

- Cumulative Global Renewable Energy Source in Electricity Installed Capacity grow 8% in 2014, or 6.6 percent in 2004-2014 (BP 2018);
- Redeployment of Renewable Energy Technology (RET) has reduced Renewable Price and Increase its availability.

I. OVERVIEW/ BACKGROUND

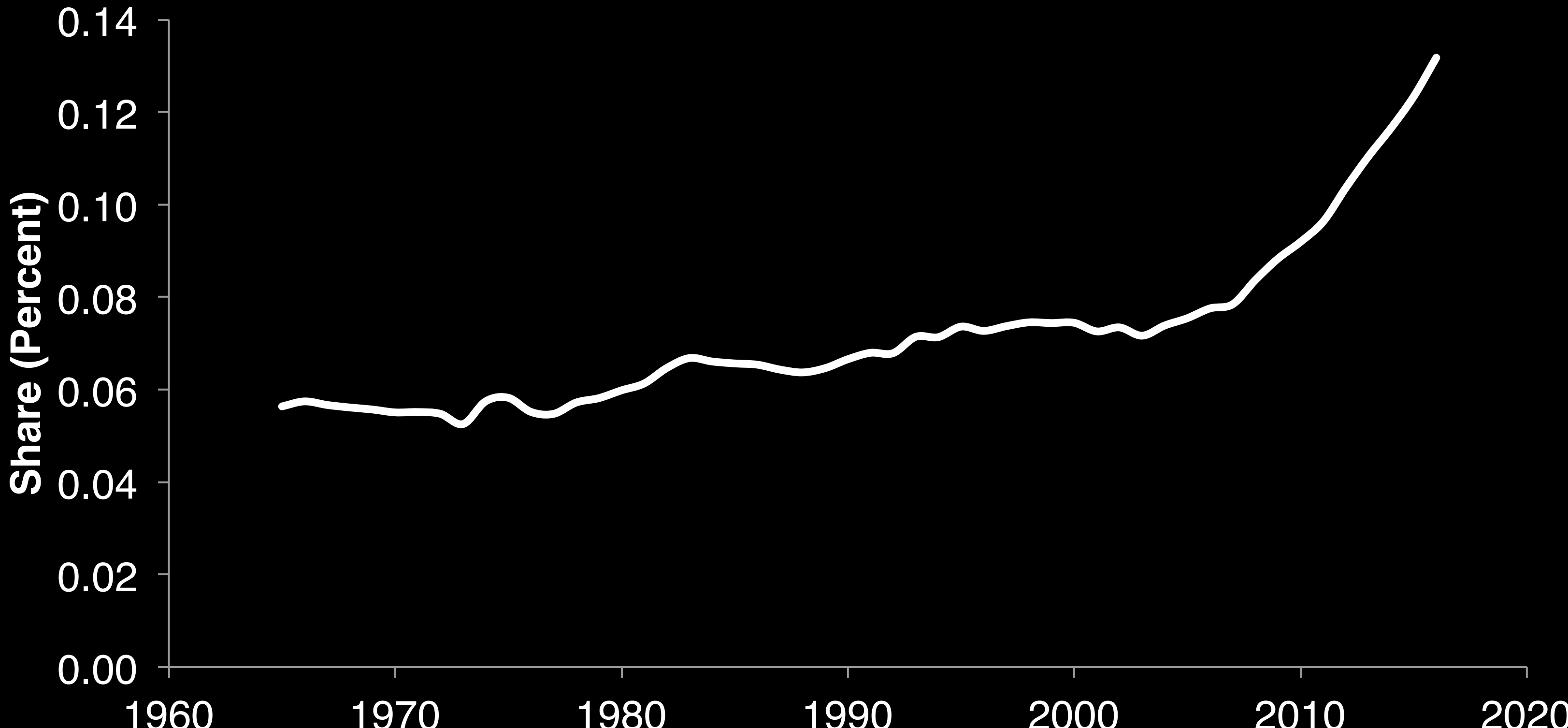
Global Levelized Cost of Electricity (LCOE) from utility-scale renewable power generation technologies, 2010-2017



Source: International Renewable Energy Agency (IRENA) 2017

I. OVERVIEW/ BACKGROUND

Renewable Share of Global Primary Energy Consumption (MToE)



Source: Author re-estimation from British Petroleum Database (2018)

I. OVERVIEW/ Renewable and Emission

- EMF22 Project (Clarke et al 2009); 11 Integrated Assessment Models assess the feasibility of climate policy to achieve certain climate target under Kyoto (550 ppmv);
- Guerney et al. (2009) with GTEM, van Vliet et al. (2009) with IMAGE 2.4 and Calvin et al. (2009) with SGM Model: confirm the significant contribution of the clean technology to achieve the lowest radiative forcing category;
- For achieving the Kyoto target in 2050, the global CO2 emission has to be reduced by 25% from year 2005 level and the share of low carbon resources to be at least 75% to the total energy mix.

I. OVERVIEW/ BACKGROUND

- Furlan & Montarino (2018) found the competition with the fossil fuel could either sustain or present the spread of the renewable, which is influential for its contribution to reduce the emission.
- This level of competition will be very different between emerging economies such as China and India to more stable economies such as the US and Europe

I. OVERVIEW/ BACKGROUND

Research Aim:

- **Re-examining contribution of Renewable Energy of Limiting Future Climate Change and Country's Strategic Interaction in Low Climate Regime especially for large emitters.**

I. OVERVIEW/ BACKGROUND

Research Approach:

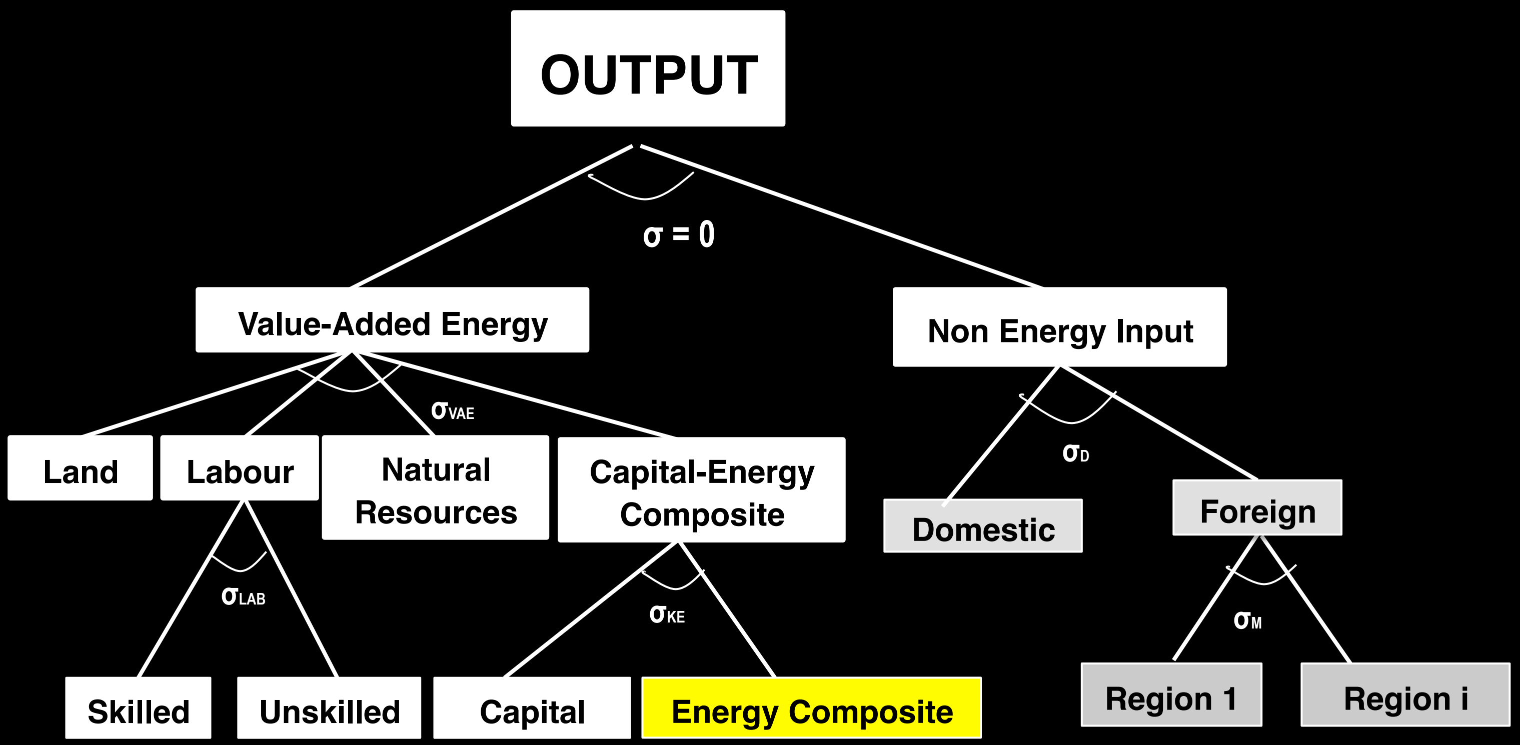
Integrated Assessment Model with:

- **Modification of Dynamic GTAP-Energy Model (Golub 2013).**
  - **A newly designed Electricity Sector incorporating Renewable Energy input;**
  - **High disaggregation Model : Capturing dynamic interaction between regions and production sectors; (including energy: coal, gas, petroleum and renewable)**
  - **Allow structural adjustment of Labour & Capital.**
- **Meta Analysis Study for Carbon Concentration and Region Specific Climate Factors of IPCC**

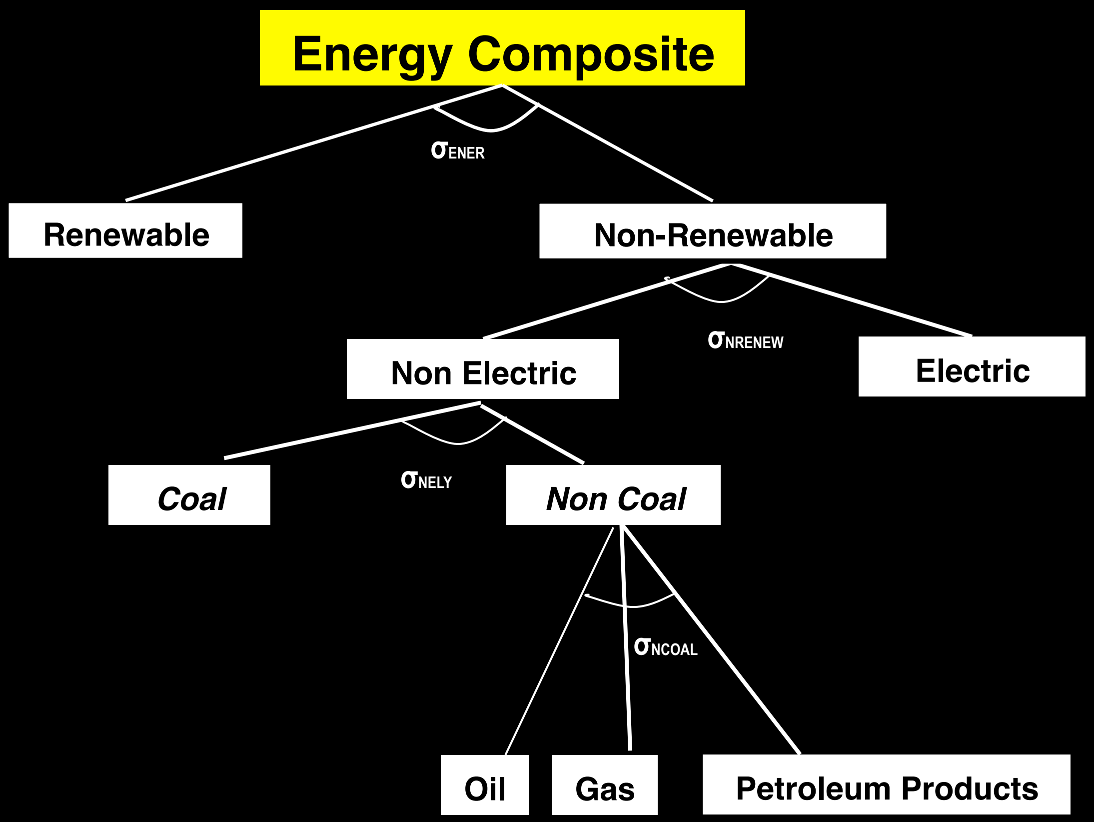
II. DATABASE AND MODELLING APPROACH

1. Dataset of GTAP 9 (2011): 140 regions, 57 sectors and 8 Factors Production;
2. Condensed to 10 regions, 12 sectors and 4 Factors Production;
3. Energy Input Share between Fossil Fuels and Renewable follow World Bank (2011)

II. DATABASE AND MODELLING APPROACH



II. DATABASE AND MODELLING APPROACH



*) The MIT- Joint Program Model (Paltsev et al 2005) and OECD_ENV Linkage Model (Chateau et al. 2014) also use the same techniques

II. DATABASE AND MODELLING APPROACH

The extension of the choice between these two energy types, mathematically presented as:

$$Y_{energy\_comp} = \left[\alpha_{NR} v_{NR}^{\frac{\sigma-1}{\sigma}} + \alpha_{R} v_{R}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Elasticity of Substitution (σ)

Energy Composite Output (Y_{energy_comp})

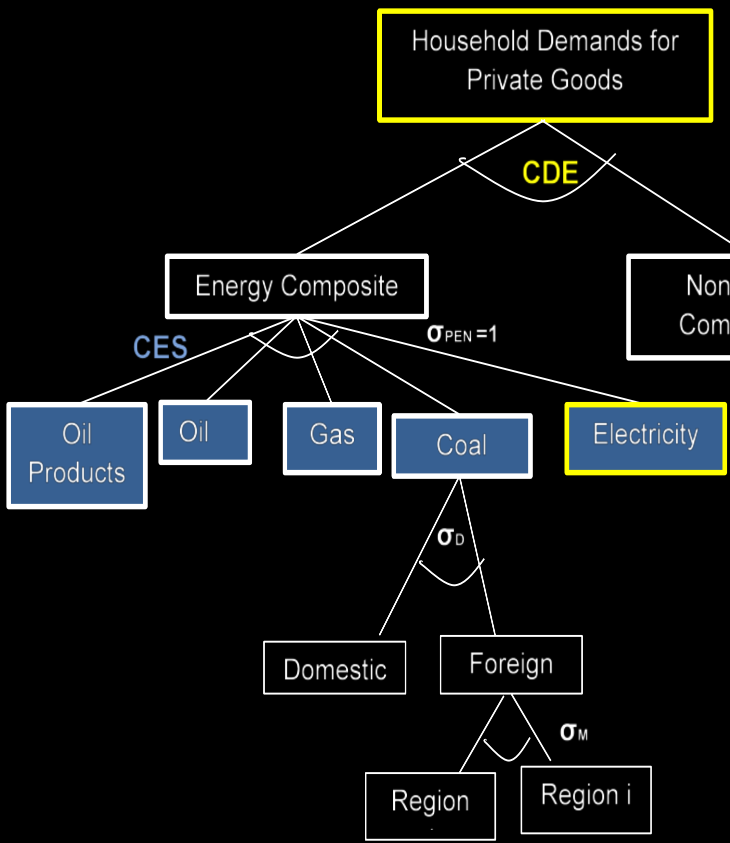
Non Renewable Energy Composite Output (v_{NR})

Renewable Energy Composite Output (v_{R})

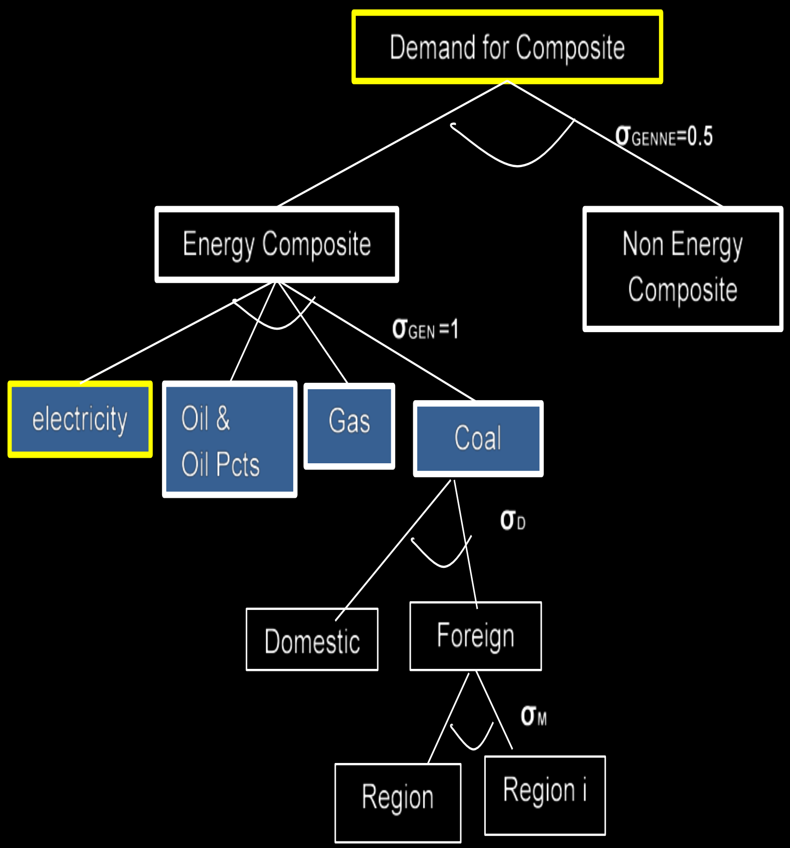
#) The elasticity between the non- renewable composite and the renewable energy sources (σ) is following Papageorguiou et al. (2013)

II. DATABASE AND MODELLING APPROACH

Household Consumption (CDE Function)



Government Consumption (CES Function)



*** HH and Government face a single electricity expenditure**

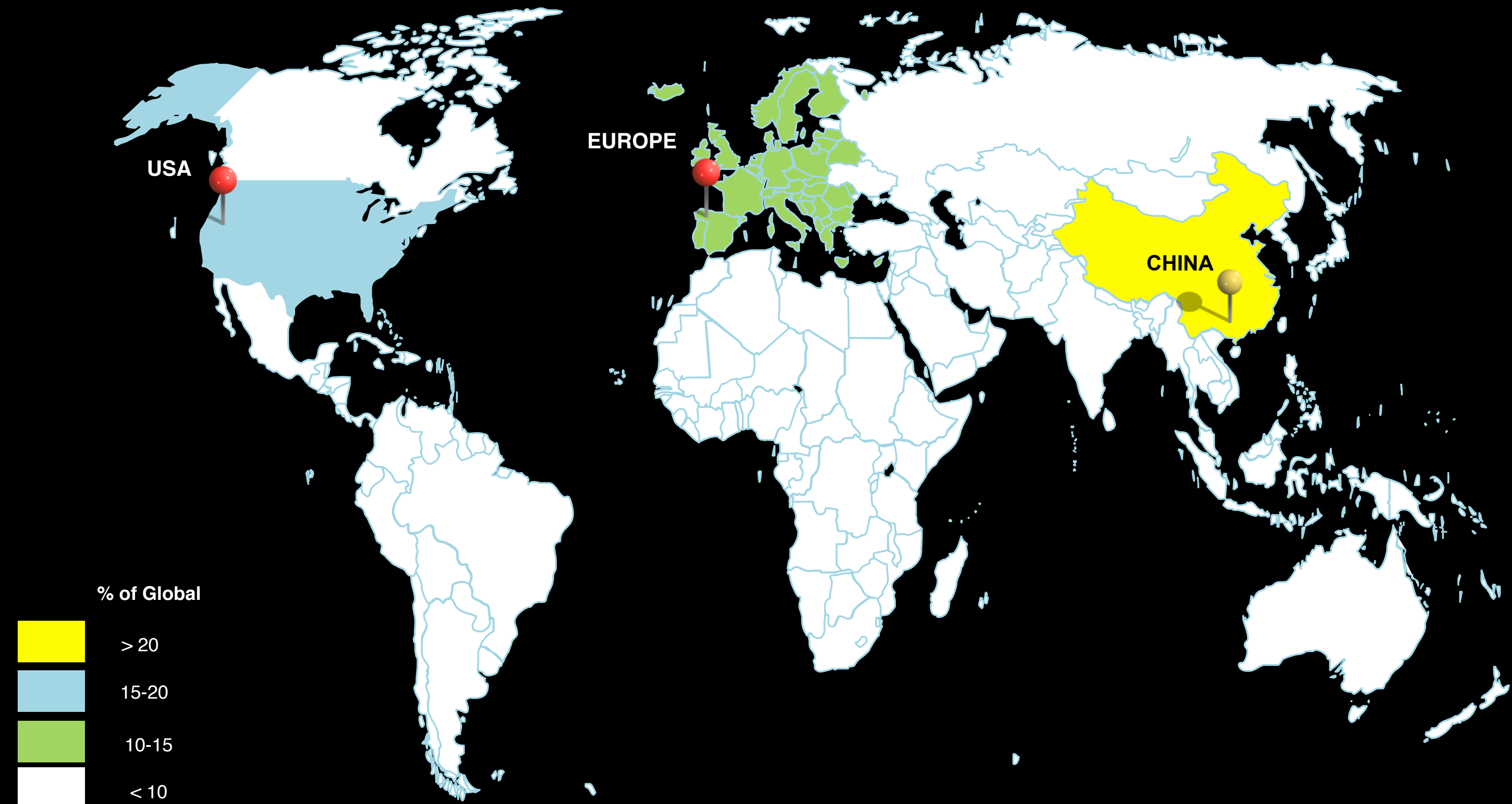
****The share of renewable expenditure (if there is any) is insignificant**

III. BASELINE SCENARIO

- Initial pre-based simulation: Calibration of changes in factor and input productivity and in risk premia were initially with exogenous path for global GDP and regional investment target following (IMF 2015);
- The estimated input productivity factor and risk premia are then used as the exogenous factors to construct the baseline economy projection where GDP and investment level are endogenously determined;
- China and India most rapidly expanding economies (>6% GDP Growth), USA and EU has modest growth (2-3%) yet share largest Nominal GDP.

III. BASELINE SCENARIO

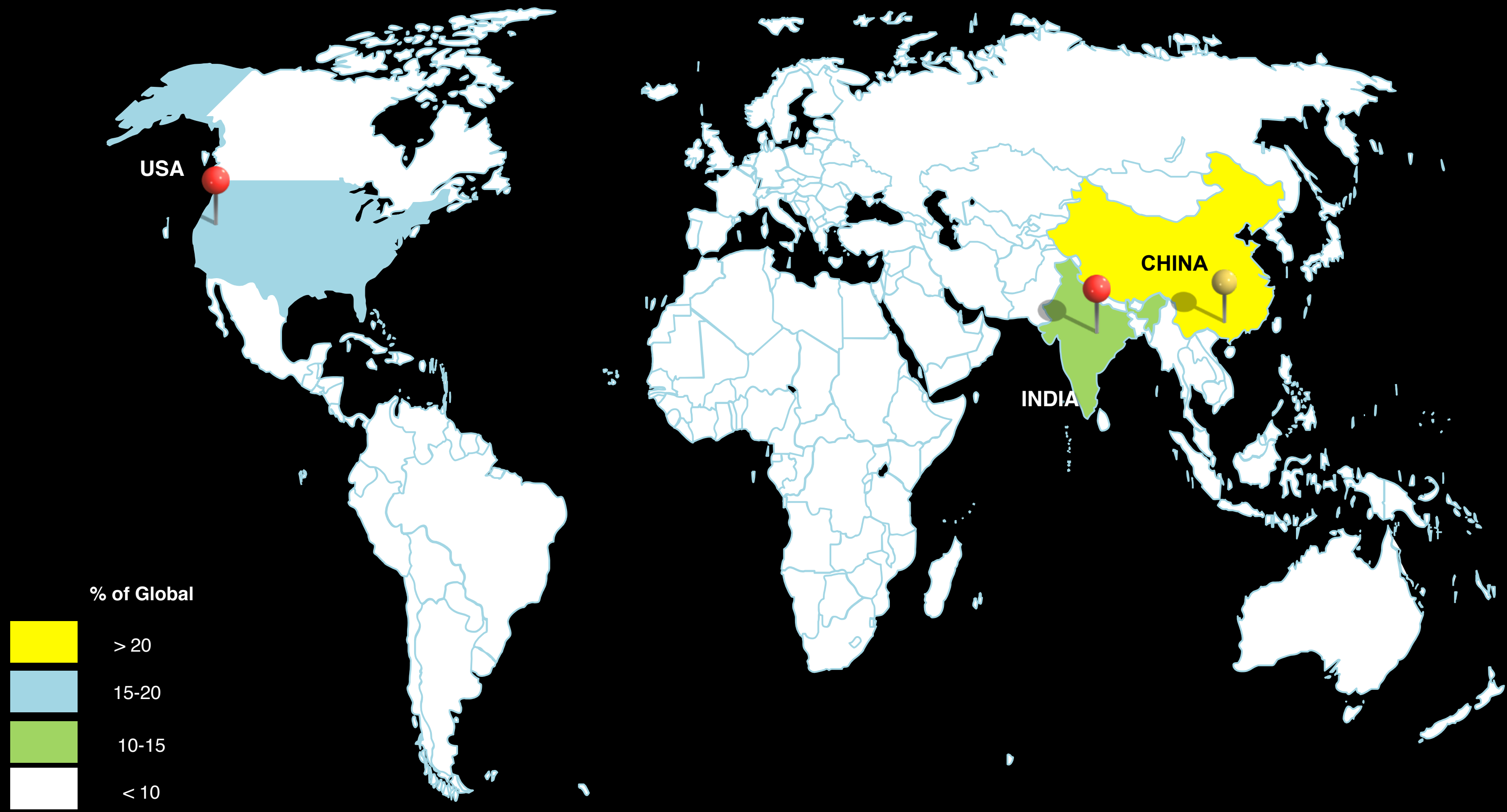
Regional Carbon Emission 2015



Source: Estimated Projection of GTAP 9 Database

III. BASELINE SCENARIO

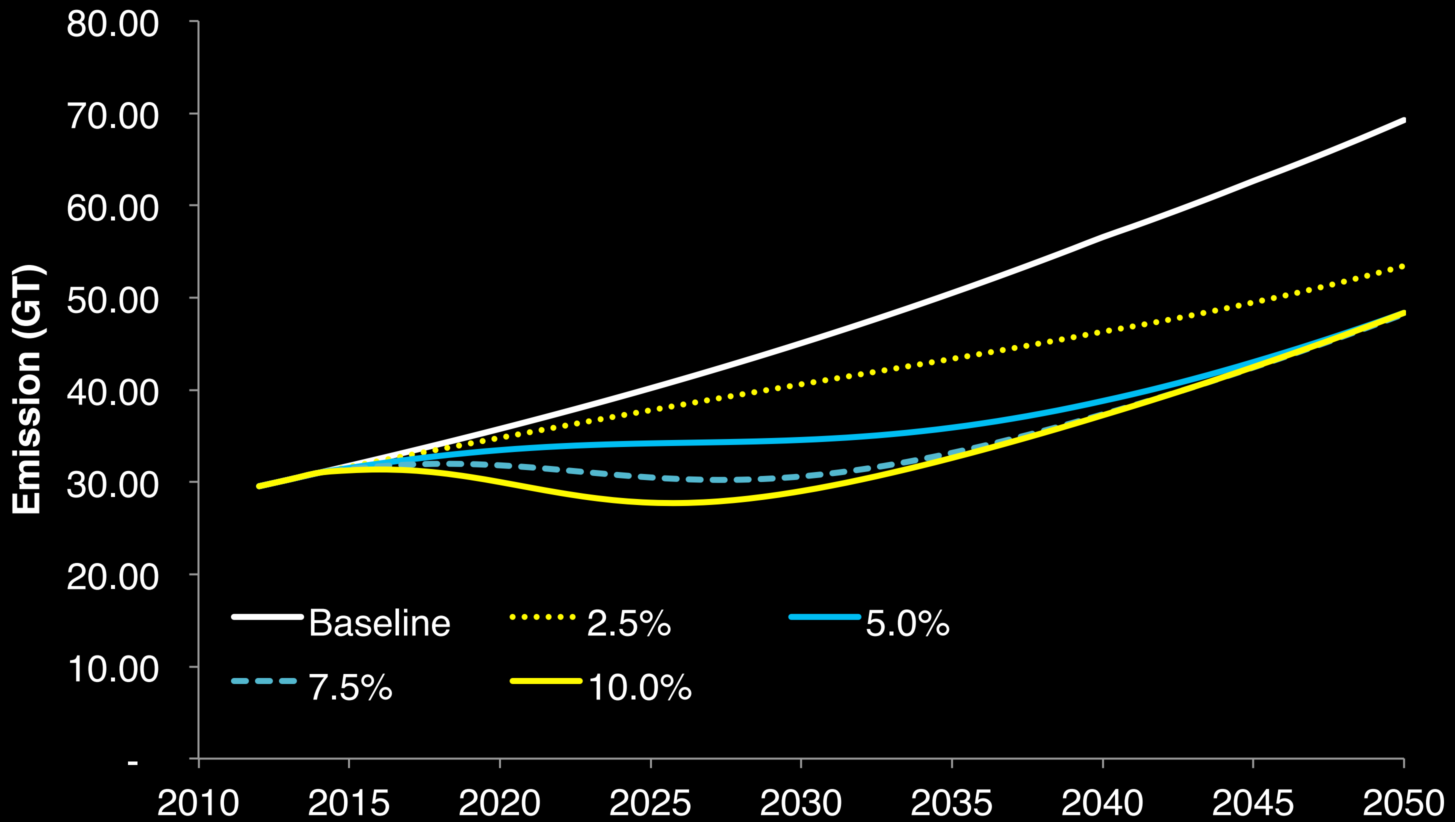
Regional Carbon Emission 2050



Source: Estimated Projection of GTAP 9 Database

IV. SCENARIO DEVELOPMENT: Renewable Productivity Shock

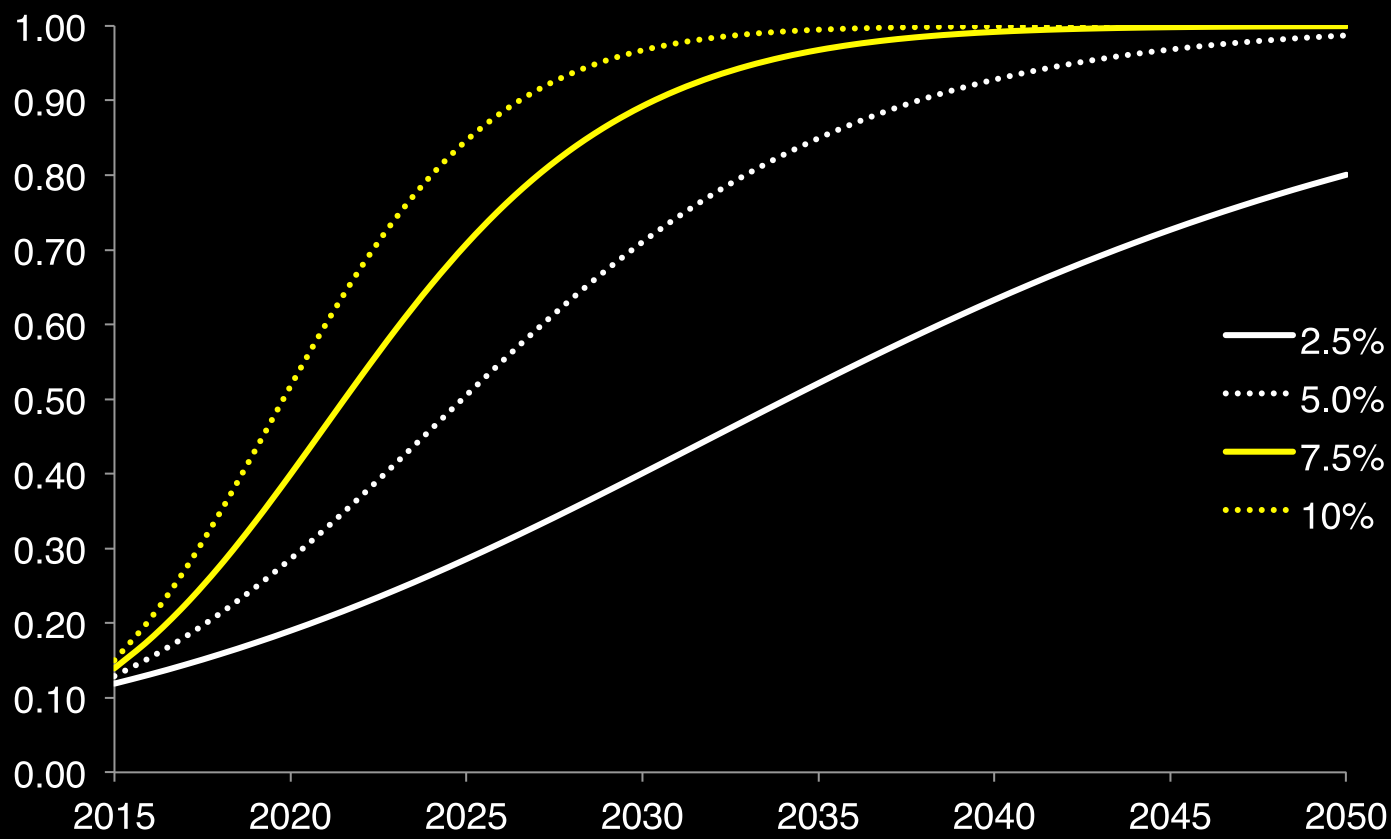
Productivity Shock in Renewable Input. Capturing current growth rate on the consumption of Renewable Energy (~6.4%)



Source: Research Estimation

IV. SCENARIO DEVELOPMENT: Renewable Productivity Shock

Renewable Input Share in Electricity Production



Source: Research Estimation

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

- Carbon pricing through taxation more effective to cut the emission.
- The impact of carbon tax on emission is immediate, direct and all substitution from fossil fuels happens in all sectors.
- Emission will be reduced at constant rate ranging 25 to 30 percent from the baseline projection, reaching 47.8 GT in 2050. Cumulative Emission is lower.
- The share of renewable in the energy mix is slightly improved. The global electricity sectors keep 75 percent fossil fuel in energy input.

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

- ***Estimating Mitigation Cost:***

  How much the economic cost for 20 USD carbon price?;

- ***Estimating Regional Climate Benefits:***

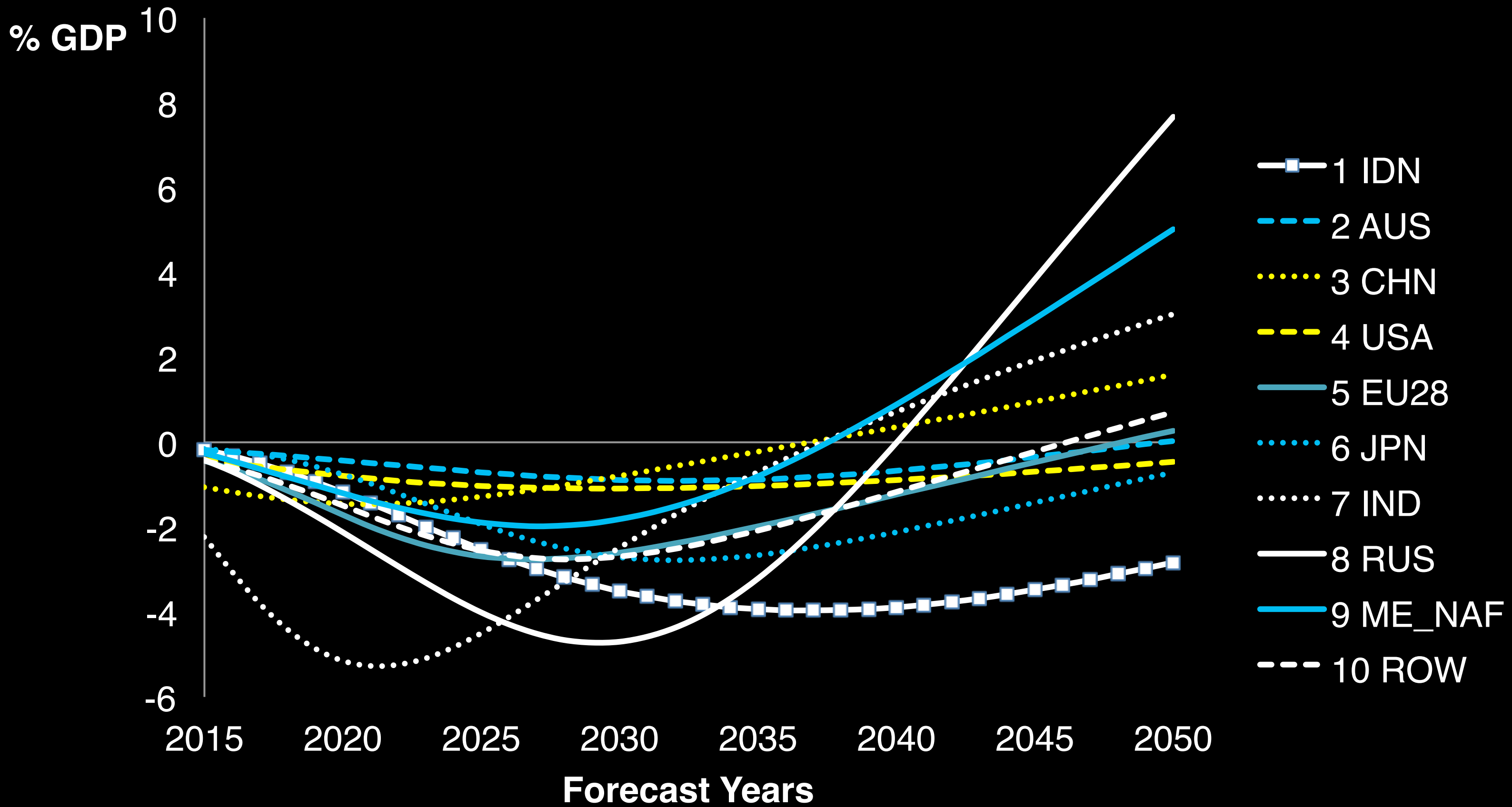
  Meta-analysis that links carbon concentration with region specific measures of economic welfare;

- ***Strategic Interactions:***

  Multiplayer Games Nash Equilibrium;

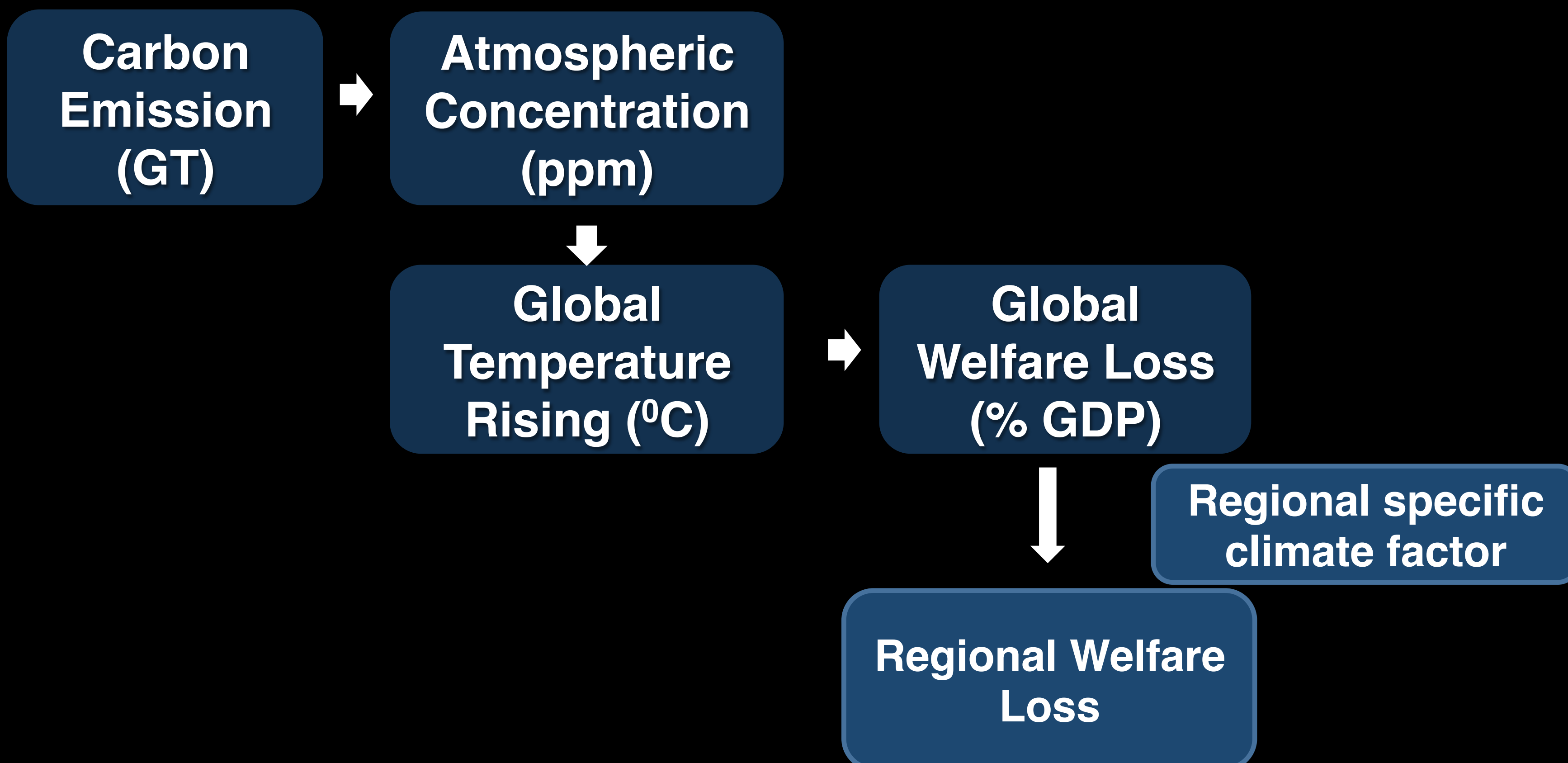
V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

Projected Real GDP Growth Deviation 20 USD Uniform Tax

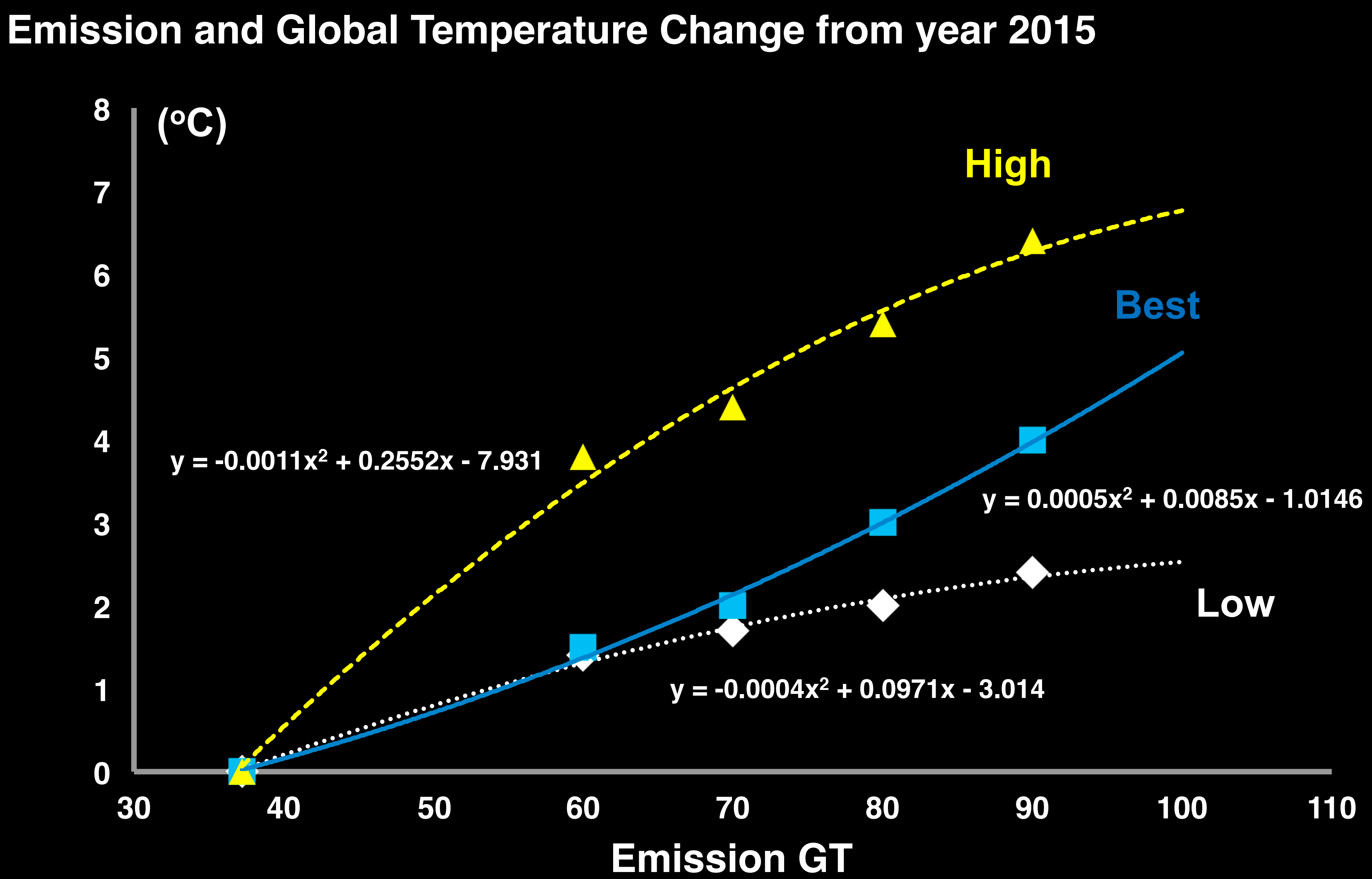


V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

Shared benefit from lower global carbon load (as % of GDP)

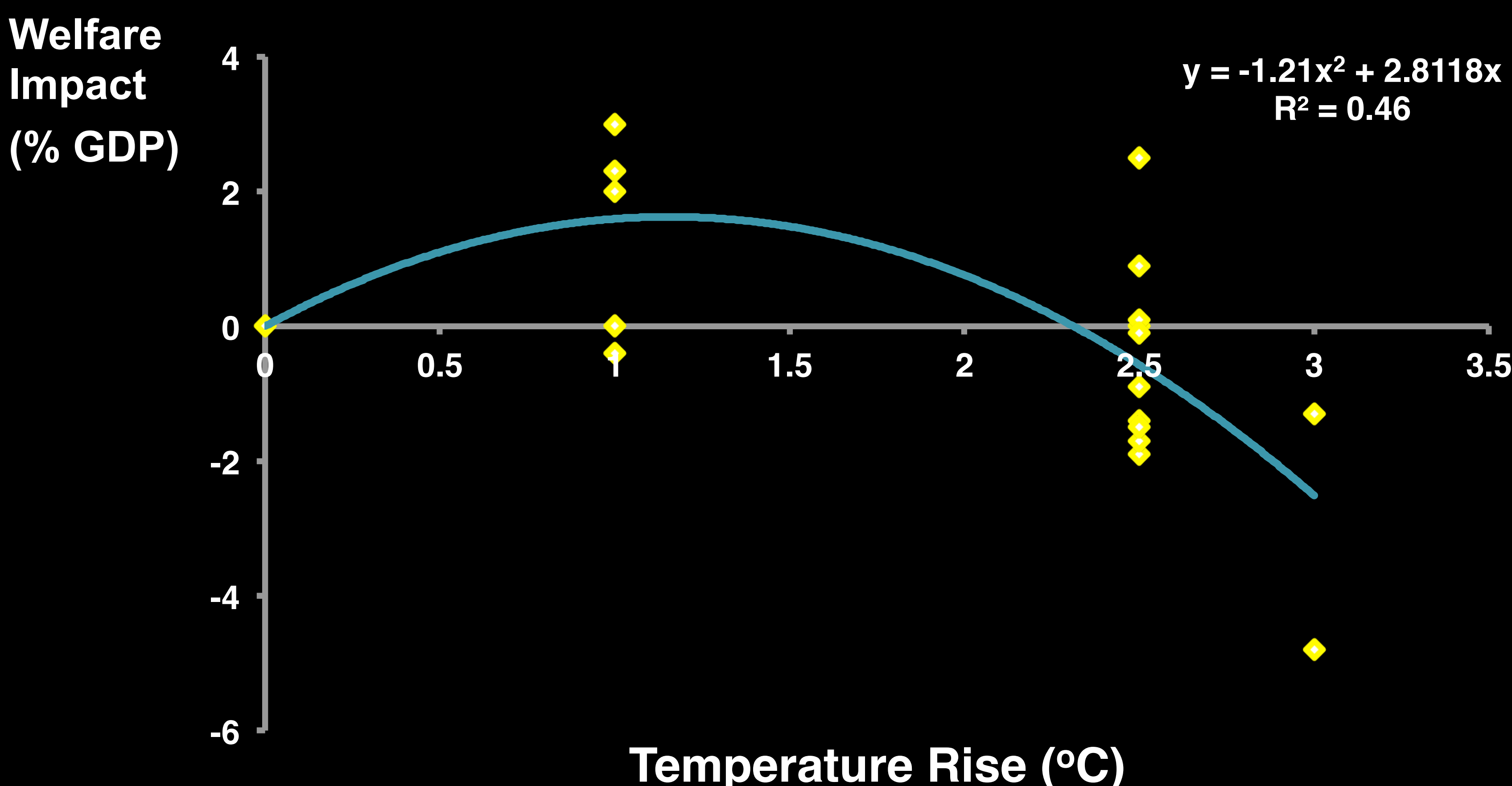


Climate Mitigation Benefit: Emission Temperature (IPCC)



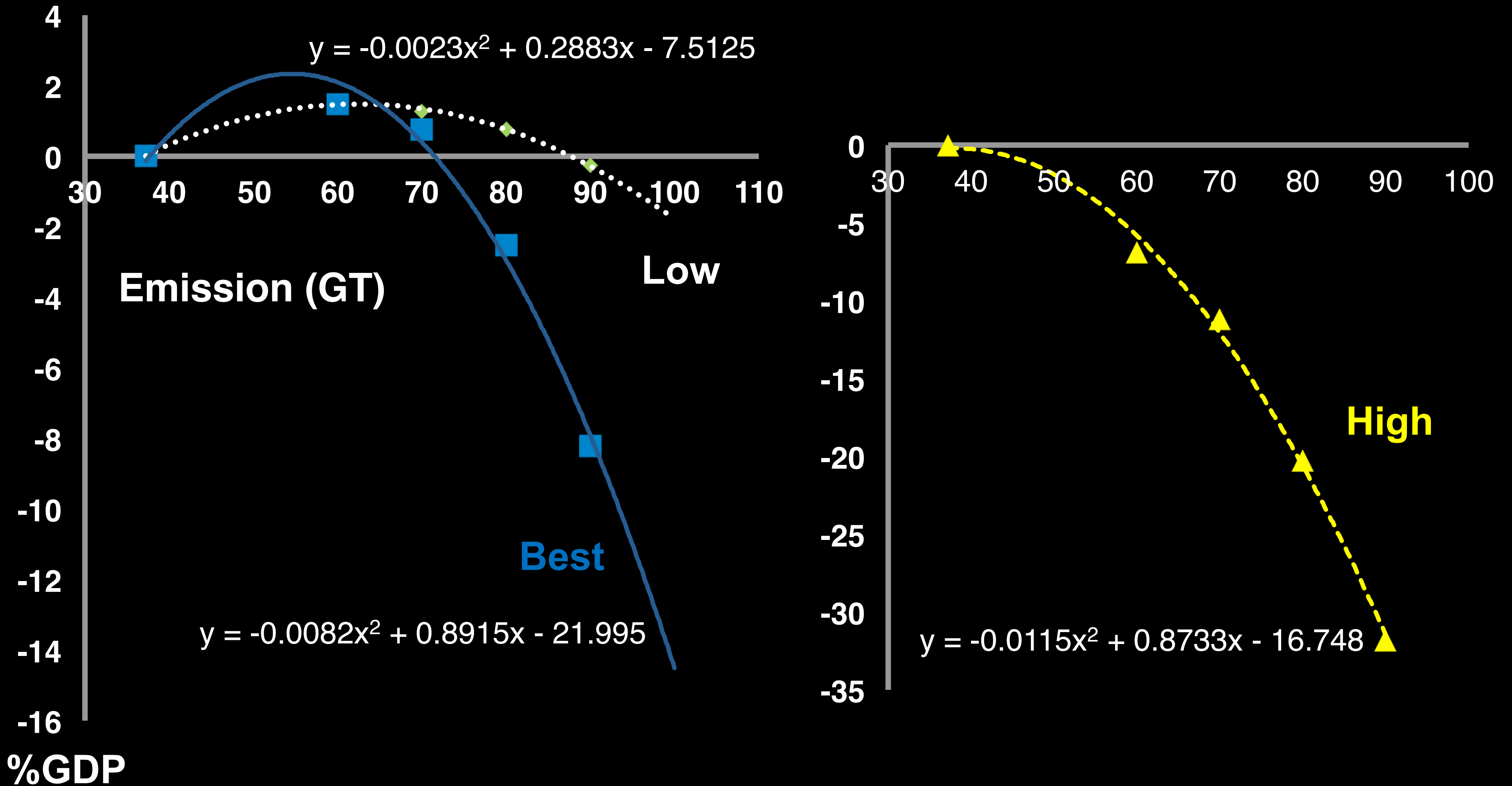
Climate Mitigation Benefit Temperature Rising & Global Welfare Impact

17 Studies of Temperature Rise & Global GDP Loss



Climate Mitigation Benefit: Total Emission and Global Welfare Reduction

Emission and Global Welfare Reduction



Climate Mitigation Benefit

Regional Welfare Benefit/Loss are based on Roson & Sartori (2015) four indicators of Climate Impact:

1. Sea Level Rise : Land Stock
2. Agricultural Productivity: Crop Yields
3. Labour Productivity : Heat and productivity in agriculture, manufacture and service sectors
4. Human Health: Vector Borne Disease

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

a. **Normal form games:** move simultaneously;

b. Construct payoff : **netting cost from shared benefit in present value term (accumulated net welfare** in **2015 USD**) for each temperature scenario;

c. Using **10 year Treasury Bond** yield rate of 0.0235;

d. **3 Players** (China, US, EU);

e. **5 Players** (China, US, EU, Indonesia, Australia).

V. RE-EXAMINING COUNTRY STRATEGIC INT. IN CARBON PRICING AGREEMENT/ 3 PLAYER

		Without Productivity Growth			With Productivity Growth		
IPCC Temperature Scenario	Country/ Region	Outcome		Extra Benefit to Defect	Outcome		Extra Benefit to Defect
		Participate	Defect		Participate	Defect	
LOW	USA	9.71	12.08	2.37	9.38	12.67	3.29
	China	11.32	14.44	3.12	14.02	25.59	11.57
	EU	9.84	14.23	4.39	5.63	9.37	3.74
BEST	USA	-21.24	-26.62	-5.38	18.37	22.07	3.7
	China	-14.28	-50.79	-36.51	25.38	37.63	12.25
	EU	-30.46	-28.84	1.62	16.46	20.33	3.87
HIGH	USA	-196.01	-217.48	-21.47	-41.83	-44.09	-2.26
	China	-220.35	-336.92	-116.57	-29.42	-60.05	-30.63
	EU	-241.77	-245.87	-4.1	-56.71	-54.97	1.74

*China & US: Participate in Best Temp Scenario

**All Participate in High Scenario

*China & US: only Participate in High Temp Scenario

V. RE-EXAMINING COUNTRY STRATEGIC INT. IN CARBON PRICING AGREEMENT/ 5 PLAYER

Without Productivity Growth | **With Productivity Growth**

IPCC Temperature Scenario	Country/ Region	Outcome (Without Productivity Growth)		Extra Benefit to Defect	Outcome (With Productivity Growth)		Extra Benefit to Defect
		Participate	Defect		Participate	Defect	
LOW	USA	9.71	12.08	2.37	9.38	12.67	3.29
	China	11.32	14.44	3.12	14.02	25.59	11.57
	EU	9.84	14.23	4.39	5.63	9.37	3.74
	Indonesia	-0.17	0.33	0.5	-0.97	-0.65	0.32
	Australia	-0.12	0.12	0.24	-0.2	-0.05	0.15
BEST	USA	-21.24	-26.62	-5.38	18.37	22.07	3.7
	China	-14.28	-50.79	-36.51	25.38	37.63	12.25
	EU	-30.46	-28.84	1.62	16.46	20.33	3.87
	Indonesia	-1.8	-1.35	0.45	-0.69	-0.36	0.33
	Australia	-0.55	-0.32	0.23	-0.1	-0.04	0.06
HIGH	USA	-196.01	-217.48	-21.47	-41.83	-44.09	-2.26
	China	-220.35	-336.92	-116.57	-29.83	-60.05	-30.22
	EU	-241.84	-245.95	-4.11	-56.73	-54.99	1.74
	Indonesia	-8.81	-8.44	0.37	-3.1	-2.8	0.3
	Australia	-2.61	-2.4	0.21	-0.81	-0.67	0.14

*China, US, EU: Participate

**Other: Free-riding

*China & US: only Participate in High Temp. Scenario

V. RE-EXAMINING COUNTRY STRATEGIC INT. IN CARBON PRICING AGREEMENT/ 5 PLAYER

IPCC Temperature Scenario	Country/ Region	Extra Benefit to Defect (No Productivity Grow) A	Extra Benefit to Defect (Renew Productivity Grow) B	B-A (Renewable Productivity Grow Affect)
LOW	USA	2.37	3.29	0.92
	China	3.12	11.57	8.45
	EU	4.39	3.74	-0.65
	Indonesia	0.5	0.32	-0.18
	Australia	0.24	0.15	-0.09
BEST	USA	-5.38	3.7	9.08
	China	-36.51	12.25	48.76
	EU	1.62	3.87	2.25
	Indonesia	0.45	0.33	-0.12
	Australia	0.23	0.06	-0.17
HIGH	USA	-21.47	-2.26	19.21
	China	-116.57	-30.22	86.35
	EU	-4.11	1.74	5.85
	Indonesia	0.37	0.3	-0.07
	Australia	0.21	0.14	-0.07

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

a. China has stronger incentives to defect from the agreement in high renewable productivity scenario. When the temperature prediction is low and medium (best), China clean energy policy could counter the climate effect . Then it's best options is defect. For extreme temperature case, committing to global agreement will avoid further welfare loss, so China will be likely to join;

b. US also has a strong motivation to defect, even not as strong as China;

c. Among the TOP 3, EU economy will be distorted more in period of global renewable productivity growth due to loosing its competitiveness. Joining the agreement means loosing more. So EU will defects in all IPCC temperature scenario;

d. Indonesia and Australia (and many other insignificant emitters) consistently choose to freeride.

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

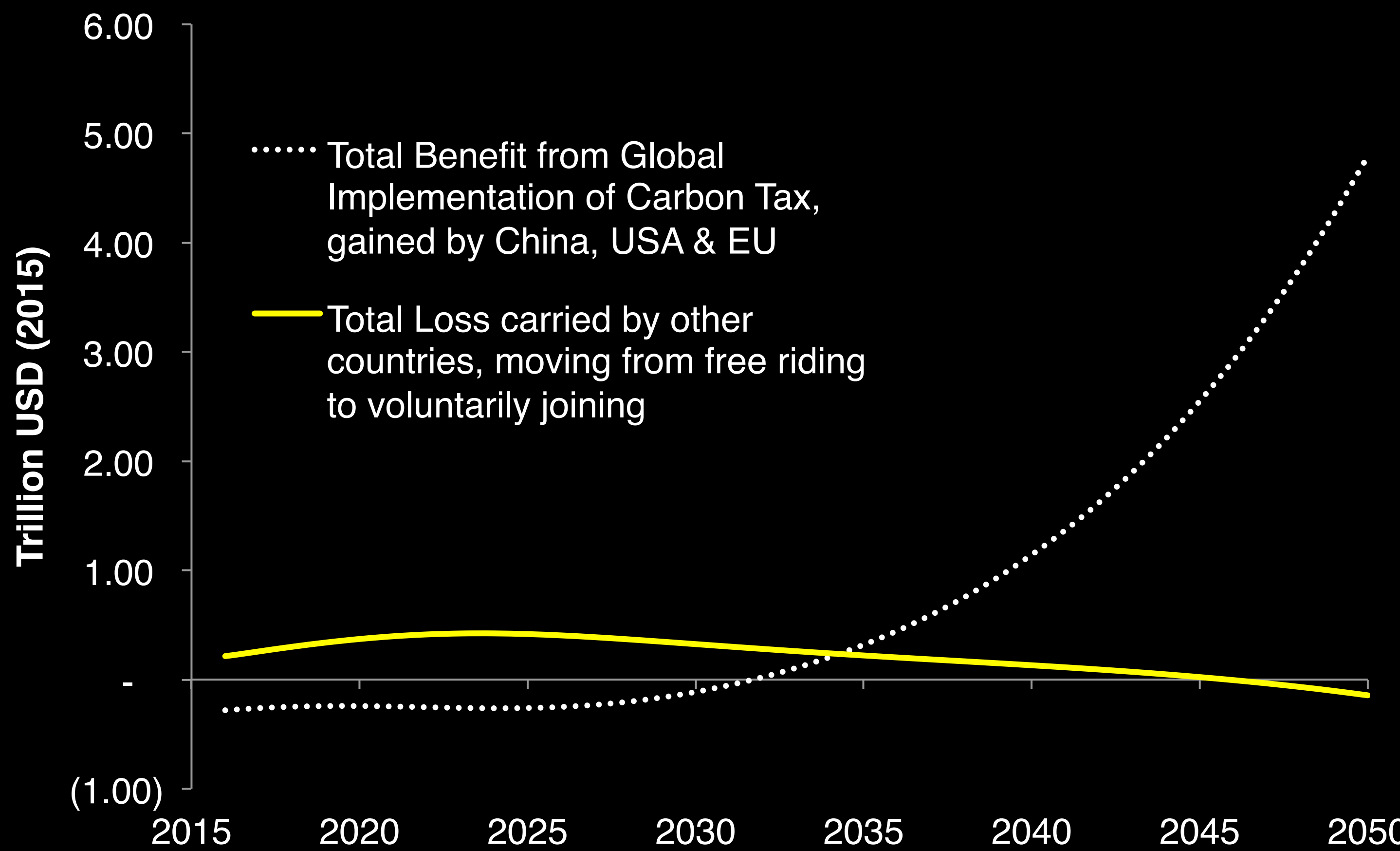
IS IT STILL BETTER OFF IF ALL JOIN THE AGREEMENT?

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

- In climate perspective, universal implementation of carbon tax will reduce GHG from 68.50 GT to 50.46 GT in 2050, improving the global welfare from 0.57 to 2.11 percent;
- However, only China and US will have unilateral gain to join the agreement in extreme temperature case. It makes global agreement with full participation is difficult;
- Transfer payment is only affordable in High (extreme) temperature case. But it still politically difficult.

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

TRANSFER PAYMENT ONLY POTENTIAL IN HIGH TEMP. CASE



VI. CONCLUSION

- To reach Kyoto Target of 550 *ppmv* in 2050, renewable productivity has to grow 2.5 % per year (to obrain the share renewable at least 75%);
- Higher productivity growth could potentially lead to green paradox effects, where rapid declining in conventional fossil fuels price triggers higher substitutability to fossil energy;
- If the productivity growth in renewable energy is sufficiently high to depress the fossil fuels consumption and creating lower emission, each country will less likely to have unilateral gain to join the climate agreement and do carbon pricing.
- For this case, China and the US will have unilateral gain only in extreme temperature case. Side payment is affordable yet still politically difficult.

“THANK YOU”

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I. OVERVIEW/ BACKGROUND

Why Renewable?
How Significant the role it will play?

- Filling Exponential Growth of Energy Demand;
- Environmental & Climate Concern: Renewable and Energy Efficiency Initiative as Integrated Policy.

I. OVERVIEW/ BACKGROUND

Renewable and Emission: Regional Analysis

The causal relationship between renewable energy and regional emission (panel co-integration): equivocal result;

(-)	(+)
• Shafiei & Salim 2014; • Robalino-López 2015; • Özbuğday & Erbas 2015; • Biglili et al 2016; • Wesseh & Lin 2016; • Jafroullah & King 2017;	• Lantz & Feng 2006; • Menyah & Wolde-Rufael 2010; • Zoundi 2017
○ Negative correlation between incremental share of renewable and the impacts on CO_2 emission	○ the renewable energy consumption has not reached a level where it can make a significant contribution to emissions reduction

III. BASELINE SCENARIO

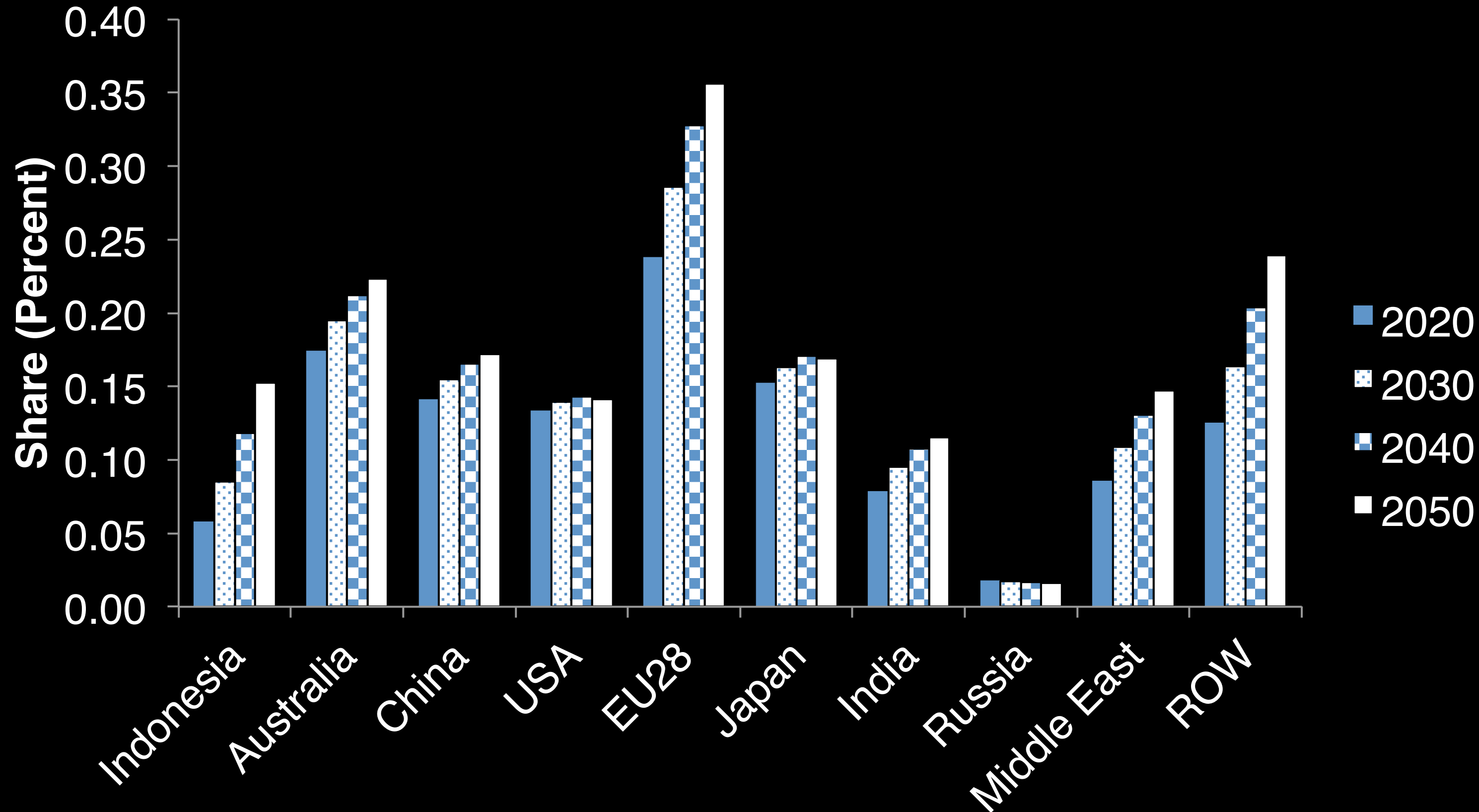
Average Growth Rate of Energy Commodities in Baseline Scenario

NO	Region	Energy Type				
		Renewable	Coal	Gas	Oil	Petroleum Products
1	Indonesia	9.24	4.90	6.53	0.32	3.07
2	Australia	3.66	0.93	1.32	-0.25	1.80
3	China	5.93	4.80	4.58	-0.59	3.59
4	USA	2.61	2.40	2.77	2.50	1.63
5	EU28	4.24	0.94	0.20	0.06	1.47
6	Japan	1.36	-0.41	-1.25	0.05	0.76
7	India	8.50	7.31	6.96	-1.05	3.81
8	Russia	1.58	1.34	1.65	2.87	1.90
9	Middle East	6.38	1.83	3.39	3.33	3.00
10	Rest of the World	5.65	2.08	1.07	0.27	2.22

Source: Estimated as described in the text

III. BASELINE SCENARIO

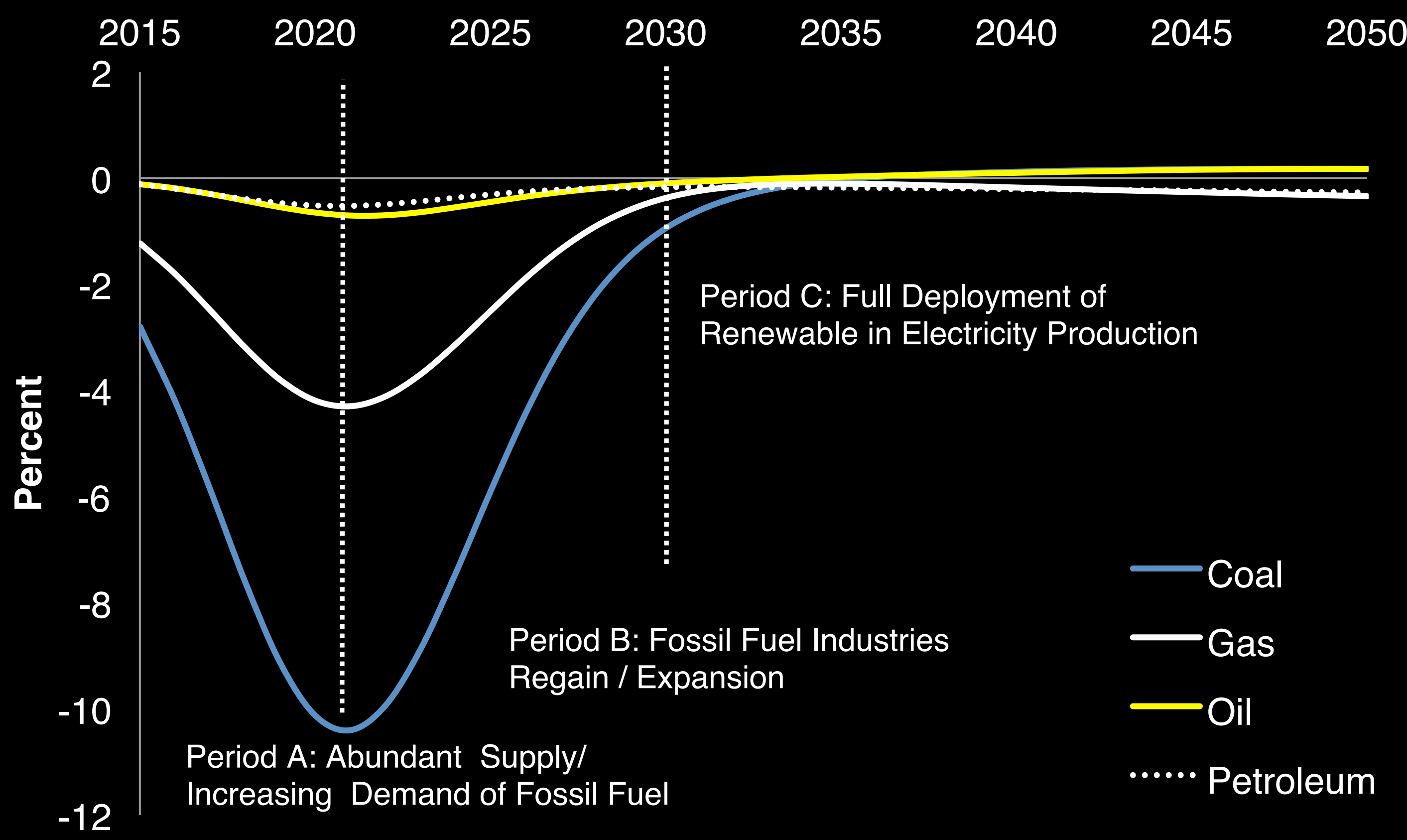
Renewable Energy Share in Energy Input of Electricity Production



Source: Estimated as described in the text

IV. SCENARIO DEVELOPMENT: Renewable Productivity Shock

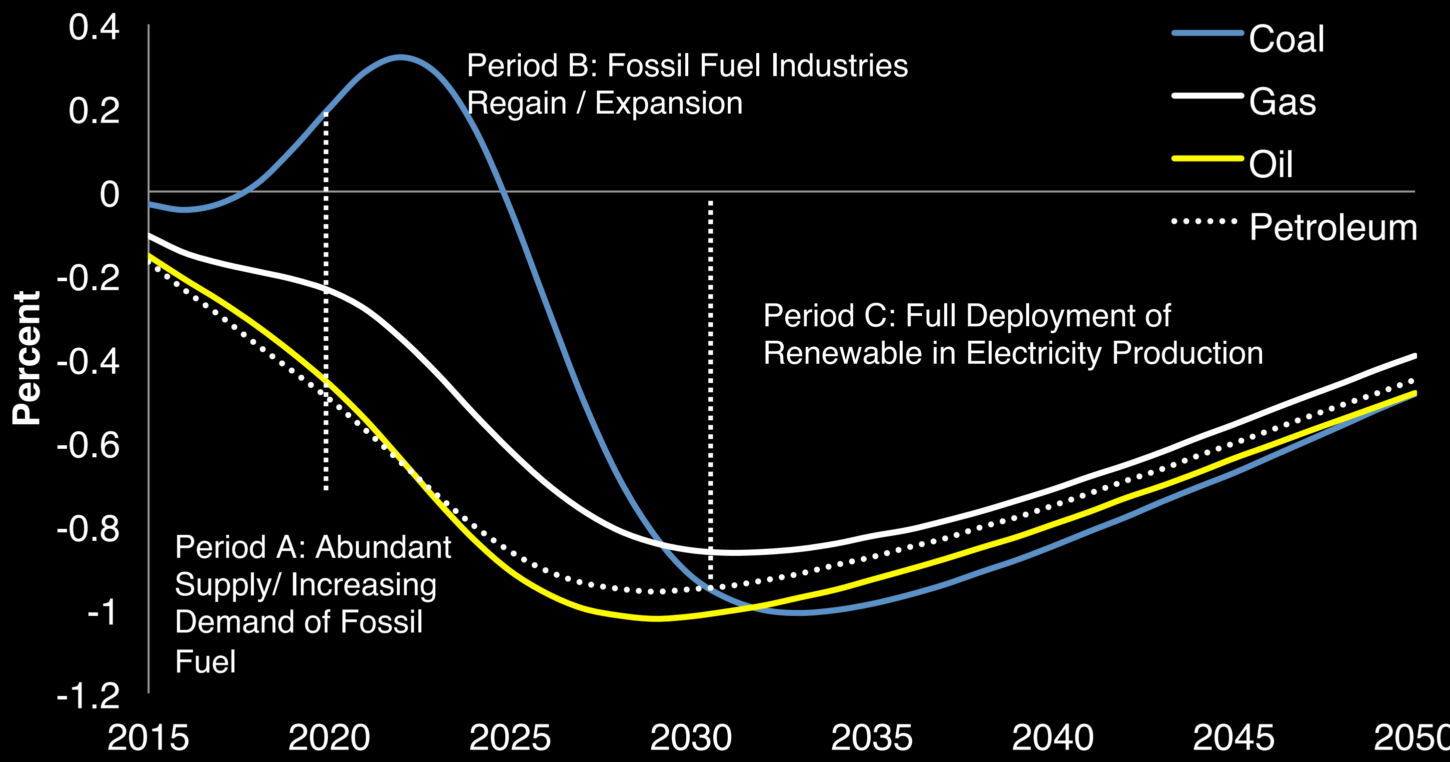
Change in Output Growth in Fossil Fuel Industry Relative to Baseline



Source: Research Estimation

IV. SCENARIO DEVELOPMENT: Renewable Productivity Shock

Change in Fossil Fuel Demand by Household Relative to Baseline



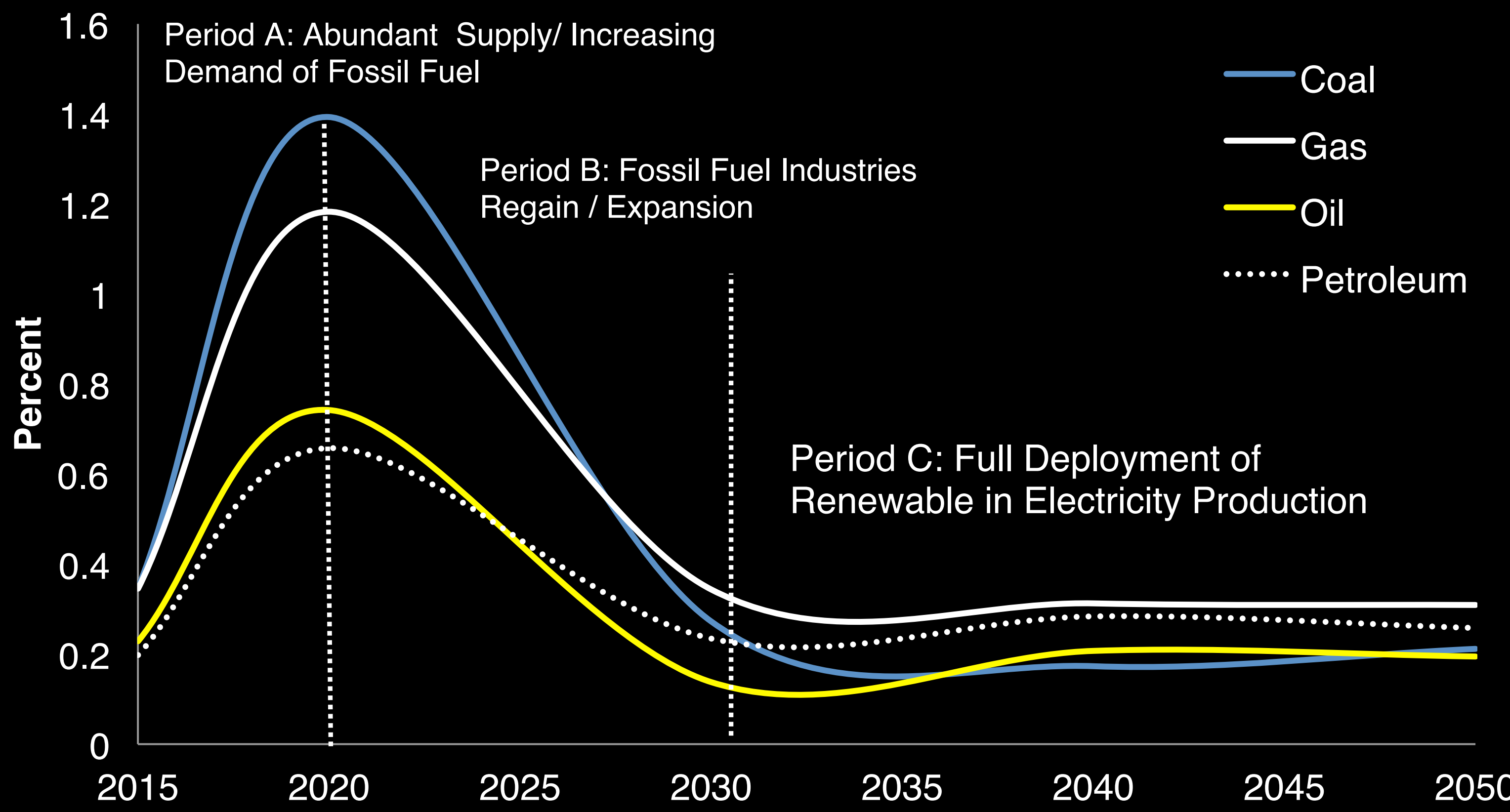
Source: Research Estimation

IV. SCENARIO DEVELOPMENT: Renewable Productivity Shock

- Higher productivity rate gives (almost) same level emission at the end of forecast period.
- Deployment of renewable technology based will create excess supply of the conventional fossil fuel energy type.
- As those are abundant, their prices descend rapidly and attract energy substitution toward fossil fuels especially for coal and gas
- The effects is greater, the higher renewable productivity shock is.
- This effect explains Green Paradox: the Unintended Consequences of Climate Policies that arguably results in moderate emission reduction (Sinn 2008 and Jensen et al. 2015)

IV. SCENARIO DEVELOPMENT: Renewable Productivity Shock

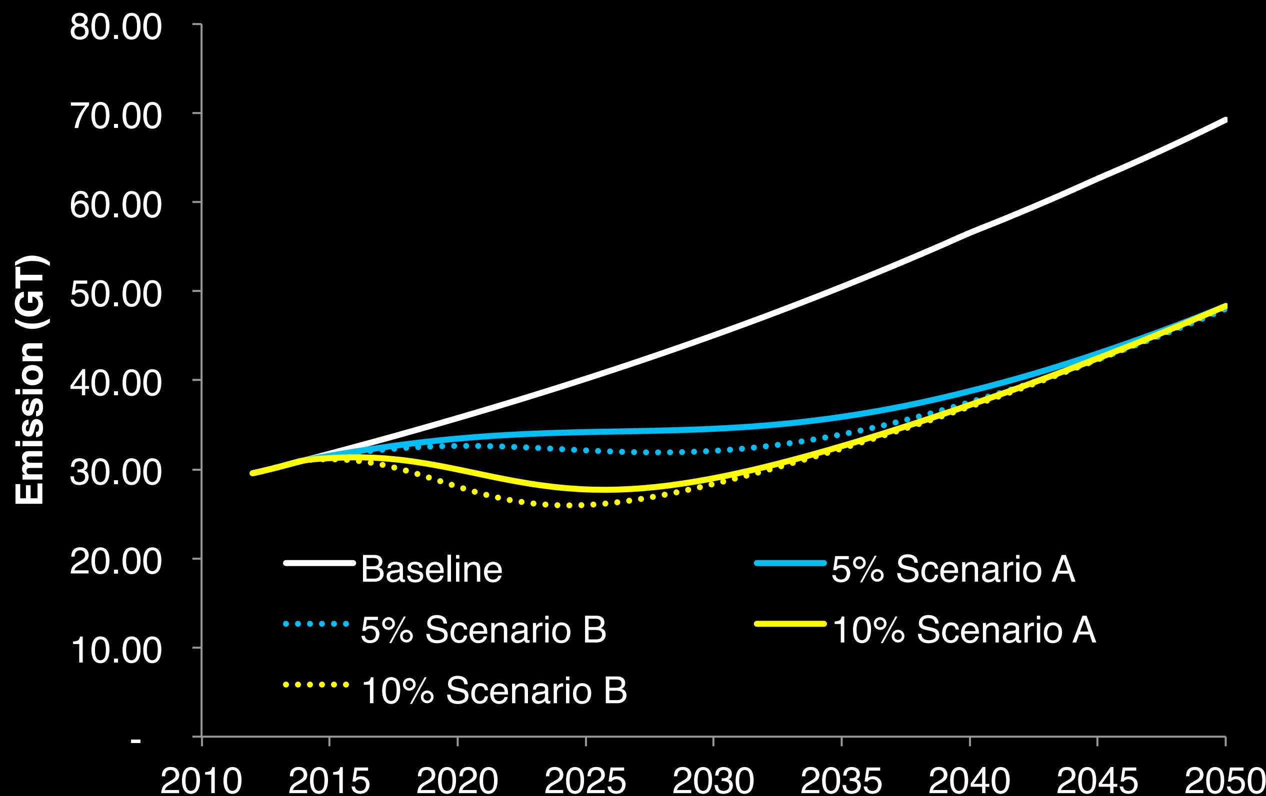
Average Growth of Global Fossil Fuel Demand in Secondary Industries Relative to Baseline



Source: Research Estimation

IV. SCENARIO DEVELOPMENT: SCENARIO B (Productivity Shock in Renewable Sector)

Technological progress in the exploration and cultivation of renewable sites results in continuous growth and abundant supply of renewable fuel.

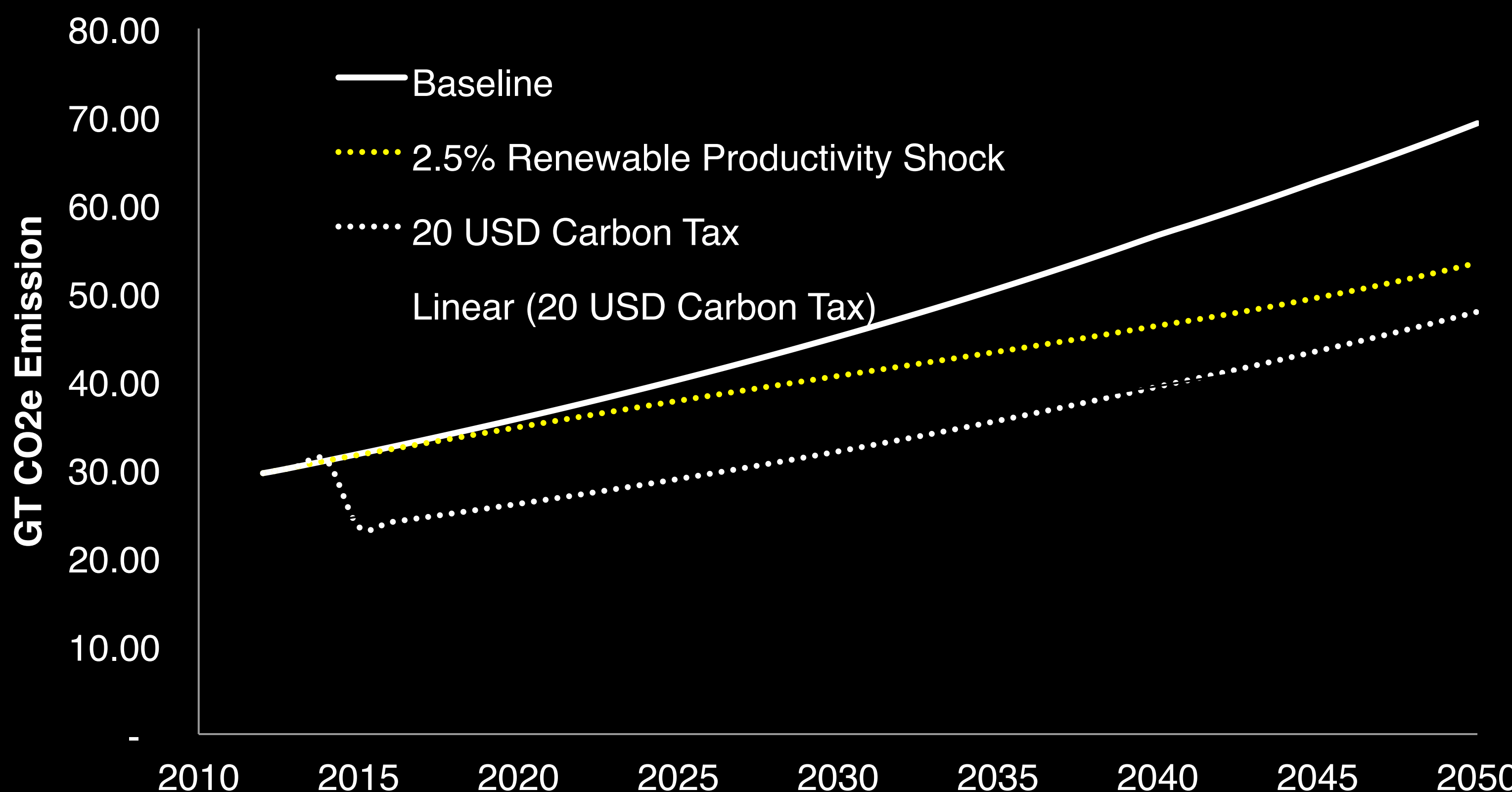


Source: Research Estimation

IV. SCENARIO DEVELOPMENT: SCENARIO A vs B

- No substantial different on Emission Level results between Productivity Shock on Renewable Input in Electricity Production (A) and Productivity shock in Renewable Sector (B);
- Two scenarios impacts differently on renewable price. As mostly renewable used in electricity production, they give same effects towards renewable energy used, followed by electricity price;
- Higher productivity rate gives (almost) same level emission at the end of forecast period.

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT



Will each region be willing to be part of global mitigation agreement in the regimes of high renewable productivity?

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

LOW Scenario (in Trillion USD)

EU: Participate

USA \ China	Participate		Defect	
Participate	3.46	12.04	9.06	24.44
		-1.40		4.77
Defect	7.28	13.62	12.40	25.40
		0.01		5.63

EU: Defect

USA \ China	Participate		Defect	
Participate	3.92	12.49	9.38	24.68
		2.57		8.57
Defect	7.69	14.02	12.67	25.59
		3.92		9.37

DSNE: All Defect

(No Prisoners' Dilemma)

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

BEST Scenario (in Trillion USD)

EU: Participate

USA \ China	Participate	Defect
Participate	9.10, 20.94, 4.98	17.86, 36.08, 14.99
Defect	14.62, 24.45, 8.39	21.70, 37.38, 16.46

EU: Defect

USA \ China	Participate	Defect
Participate	10.14, 22.04, 9.62	18.37, 36.48, 19.02
Defect	15.51, 25.38, 12.86	22.07, 37.63, 20.33

DSNE: All Defect

(No Prisoners’ Dilemma)

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

HIGH Scenario (in Trillion USD)

EU Participate

USA \ China	Participate	Defect
Participate	-19.96 -24.77 -27.76	-40.51 -51.45 -51.30
Defect	-19.76 -28.21 -30.52	-42.62 -57.91 -56.71

EU Defect

USA \ China	Participate	Defect
Participate	-20.56 -25.79 -25.02	-41.83 -53.42 -49.38
Defect	-20.53 -29.42 -27.96	-44.09 -60.05 -54.97

Only China Participate

V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

LOW SCENARIO (TRILLION USD)

NO	COUNTRY	PARTICIPATION	
		PARTICIPATE	DEFECT
1	US	9.38	12.67
2	China	14.02	25.59
3	EU	5.63	9.37
4	Indonesia	-0.97	-0.65
5	Australia	-0.20	-0.05

DSNE: ALL DEFECT

BEST SCENARIO (TRILLION USD)

NO	COUNTRY	PARTICIPATION	
		PARTICIPATE	DEFECT
1	US	18.37	22.07
2	China	25.38	37.63
3	EU	16.46	20.33
4	Indonesia	-0.69	-0.36
5	Australia	-0.10	0.04

DSNE: ALL DEFECT

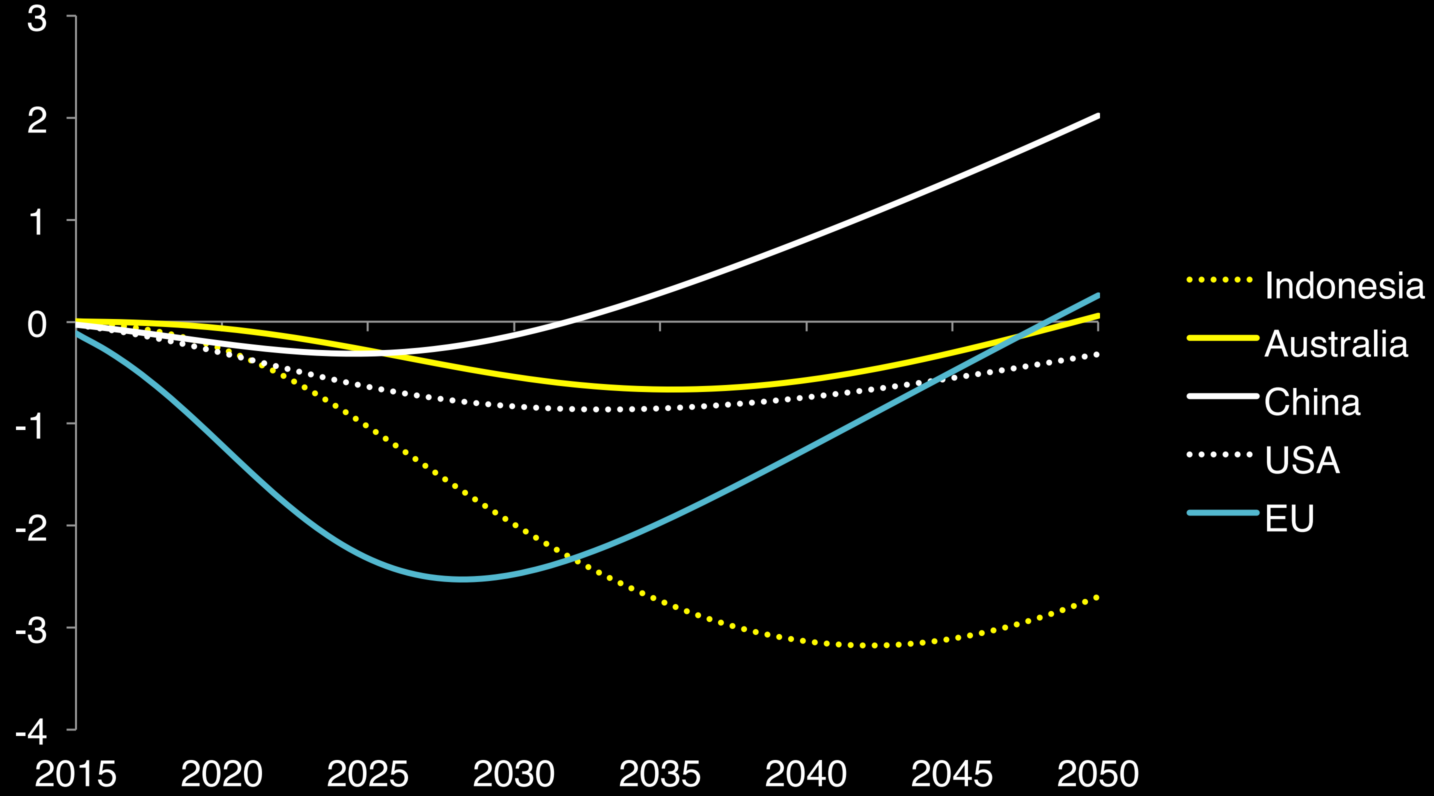
HIGH SCENARIO (TRILLION USD)

NO	COUNTRY	PARTICIPATION	
		PARTICIPATE	DEFECT
1	US	-41.83	-44.09
2	China	-29.42	-60.05
3	EU	-56.73	-54.99
4	Indonesia	-3.10	-2.80
5	Australia	-0.81	-0.67

DSNE: EU, Indonesia & Australia Free Riding

V. RE-EXAMINING COUNTRY STRATEGIC INT. IN CARBON PRICING AGREEMENT/ 5 PLAYER

GDP Change due to Global Renewable Shock (No Carbon Pricing)



Appendix: Climate Mitigation Benefit

- Mitigation scenarios give projected total carbon emissions in 2050
- Baseline (No country) : 100.2 GT; All countries 64 GT;
- Match total emissions with IPCC Global Temperature Scenario

Emission (GT) in 2050/ Lower Border	IPCC (GHG scenario)	Atmospheric Concentration (PPM)	Best Temperature Estimate (^{0}C)	Likely Uncertainty Range (^{0}C)
90	A1F1	660-790	4	2.4-6.4
80	A2	570-660	3	2.0-5.4
70	A1B	485-570	2.8	1.7-4.4
60	A1T	440-485	2.4	1.4-3.8

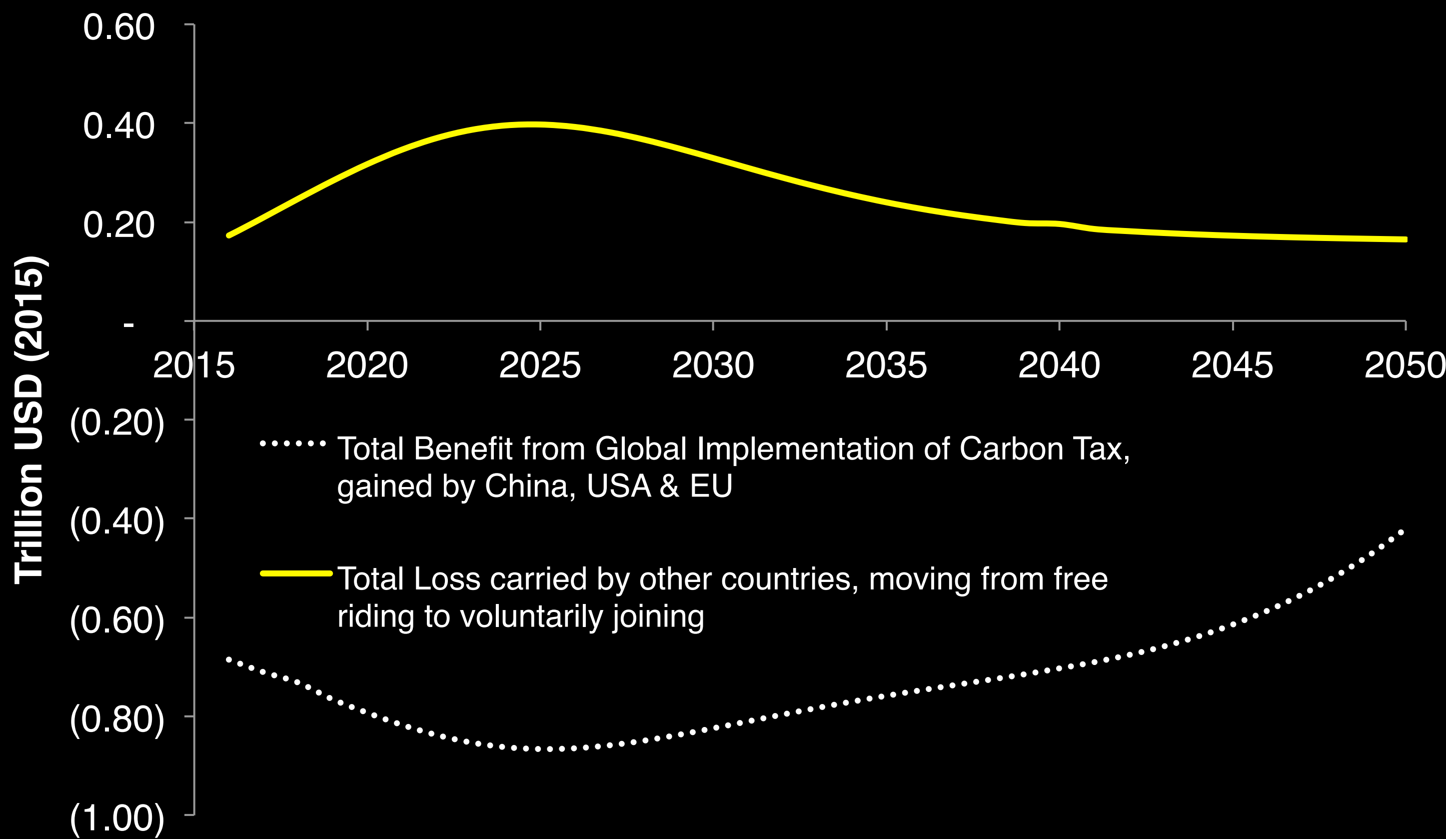
- ❖ Note: The IPCC scenarios use year 2005 as baseline, then projected until year 2100. Comparative table above shows its projection in 2050
- ❖ Atmospheric Concentration of GHG in 2005 is 379 ppm

Appendix Normalized Regional Climate Benefit Factor

No	COUNTRY/ REGION	Temperature Rising +1°C	+2°C	+3°C	+4°C	+5°C	AVERAGE
1	Indonesia	0.36	0.82	1.14	1.10	0.98	0.88
2	Singapore	0.08	0.14	0.18	0.17	0.15	0.14
3	Malaysia	0.19	0.32	0.41	0.38	0.34	0.33
4	Other ASEAN	0.33	0.57	0.73	0.70	0.63	0.59
5	Other Asia	0.88	1.16	1.34	1.29	1.21	1.17
6	Australia	0.20	0.23	0.25	0.25	0.25	0.24
7	New Zealand & Oceania	0.09	0.07	0.07	0.07	0.07	0.07
8	China (PRC)	3.97	3.82	3.79	3.79	3.80	3.83
9	Japan	0.76	0.77	0.85	0.94	1.02	0.87
10	Korea	0.18	0.18	0.18	0.20	0.21	0.19
11	India	1.74	2.32	2.68	2.52	2.31	2.32
12	Brazil	0.37	0.58	0.75	0.81	0.81	0.66
13	USA	2.76	2.50	2.34	2.29	2.35	2.45
14	Canada	0.41	0.17	0.01	0.04	0.09	0.14
15	Other America	0.85	1.64	1.87	1.88	1.75	1.60
16	EU_28	4.70	2.75	1.50	1.70	2.16	2.56
17	Russia	0.62	0.28	0.05	0.08	0.16	0.24
18	FTA Europe	0.15	0.08	0.04	0.04	0.06	0.07
19	Ex. Soviet Union & Other EU	0.43	0.29	0.20	0.21	0.24	0.27
20	Middle East	1.24	1.15	1.10	1.07	1.06	1.13
21	Africa	0.69	1.18	1.53	1.47	1.35	1.24

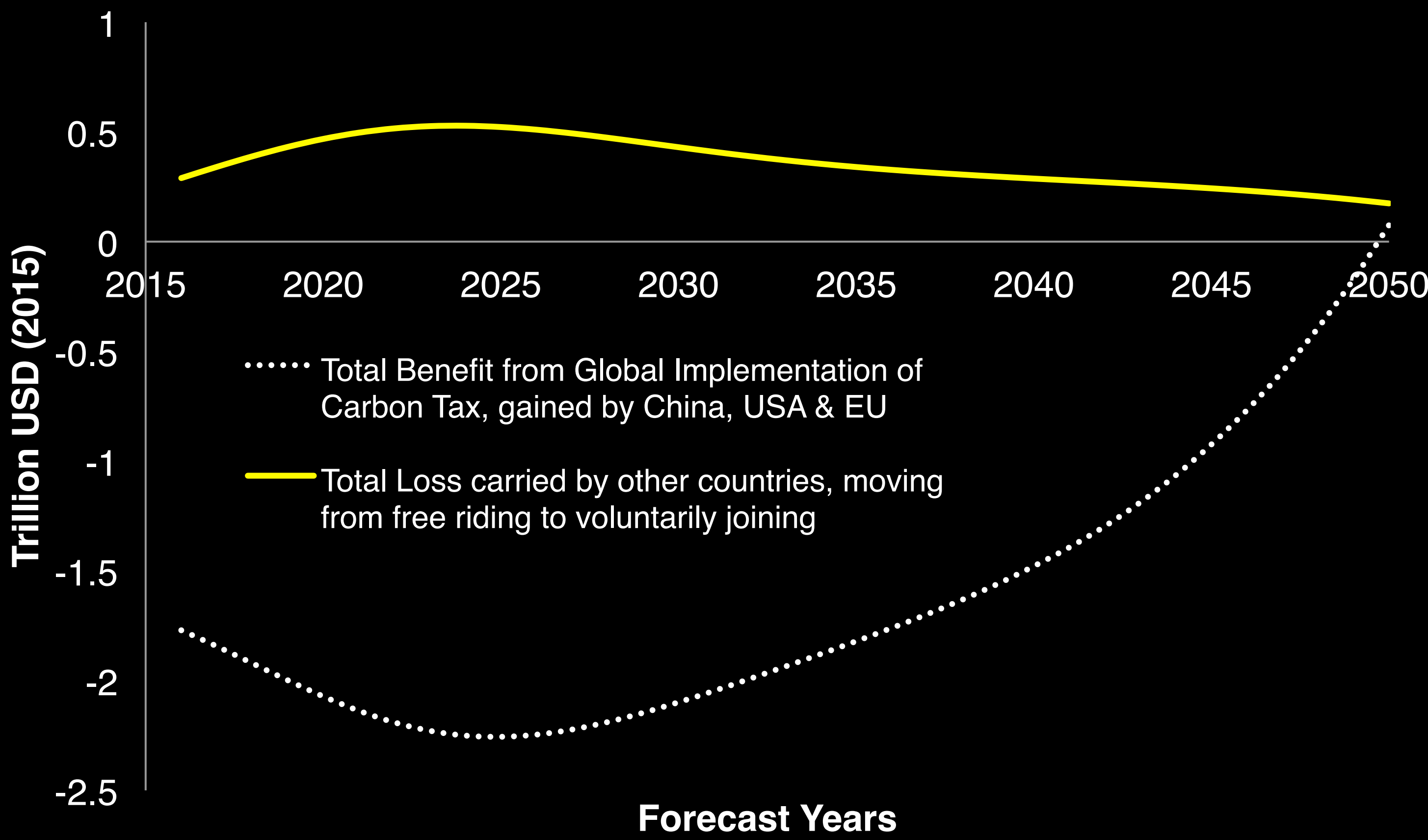
V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

TRANSFER PAYMENT IN LOW TEMP. CASE



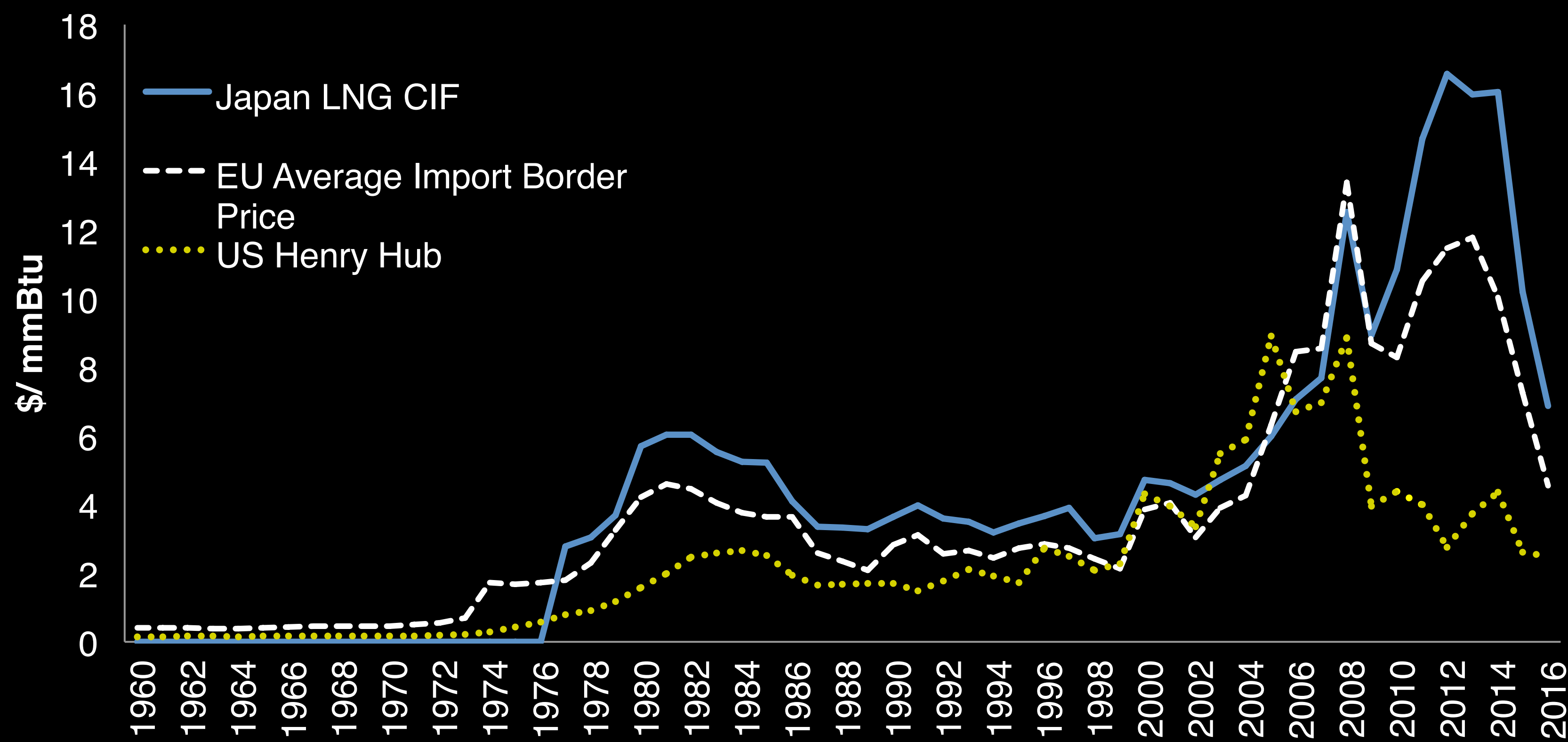
V. RE-EXAMINING COUNTRY STRATEGIC INTERACTION IN CARBON PRICING AGREEMENT

TRANSFER PAYMENT IN BEST TEMP. CASE



IV. SCENARIO C (RECENT DEVELOPMENT OF GAS)

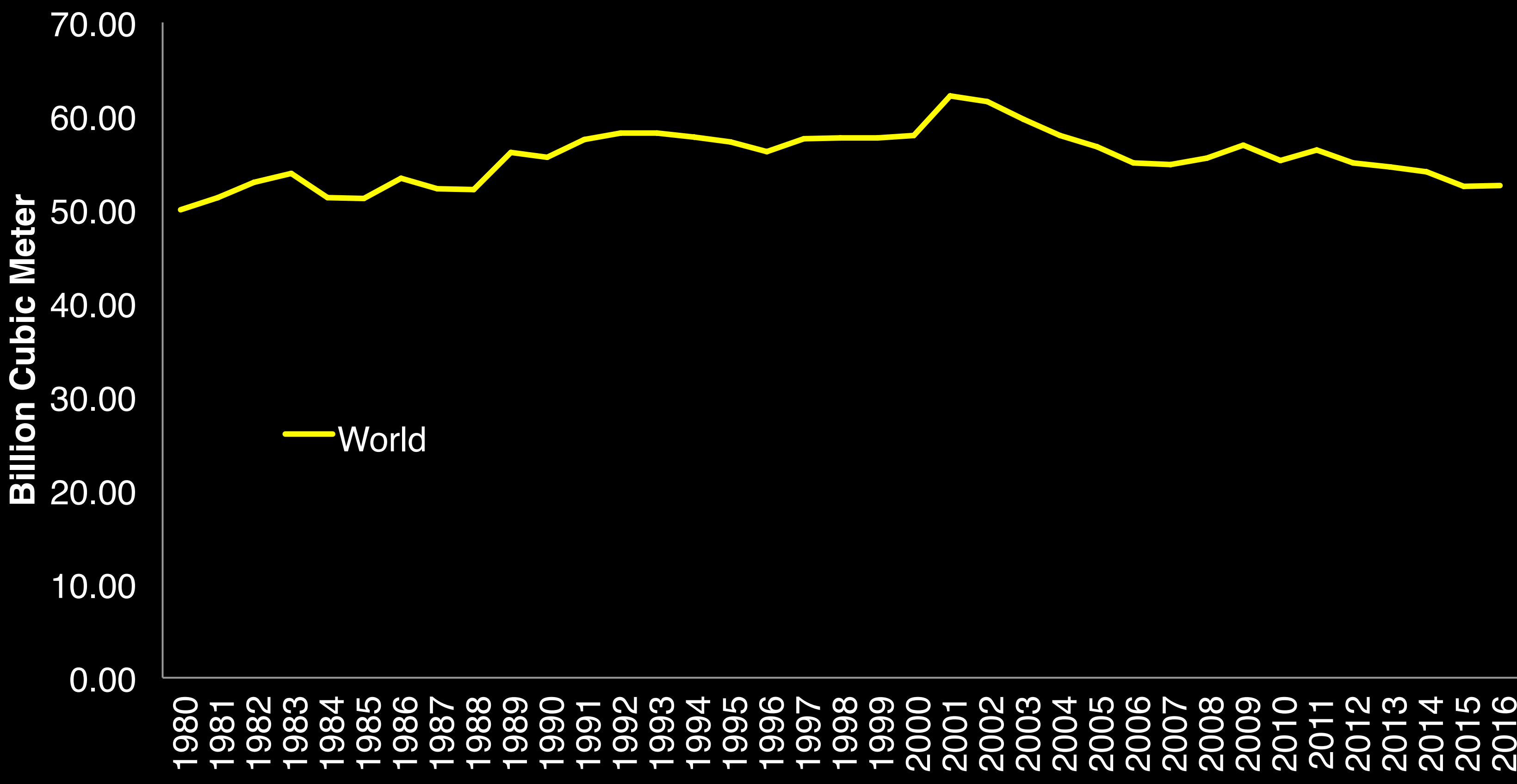
Historical Trends in Natural Gas Price (Nominal USD per Million British thermal unit/ MMBtu)



Source: Author re-estimation from British Petroleum Database (2018)

IV. SCENARIO C (RECENT DEVELOPMENT OF GAS)

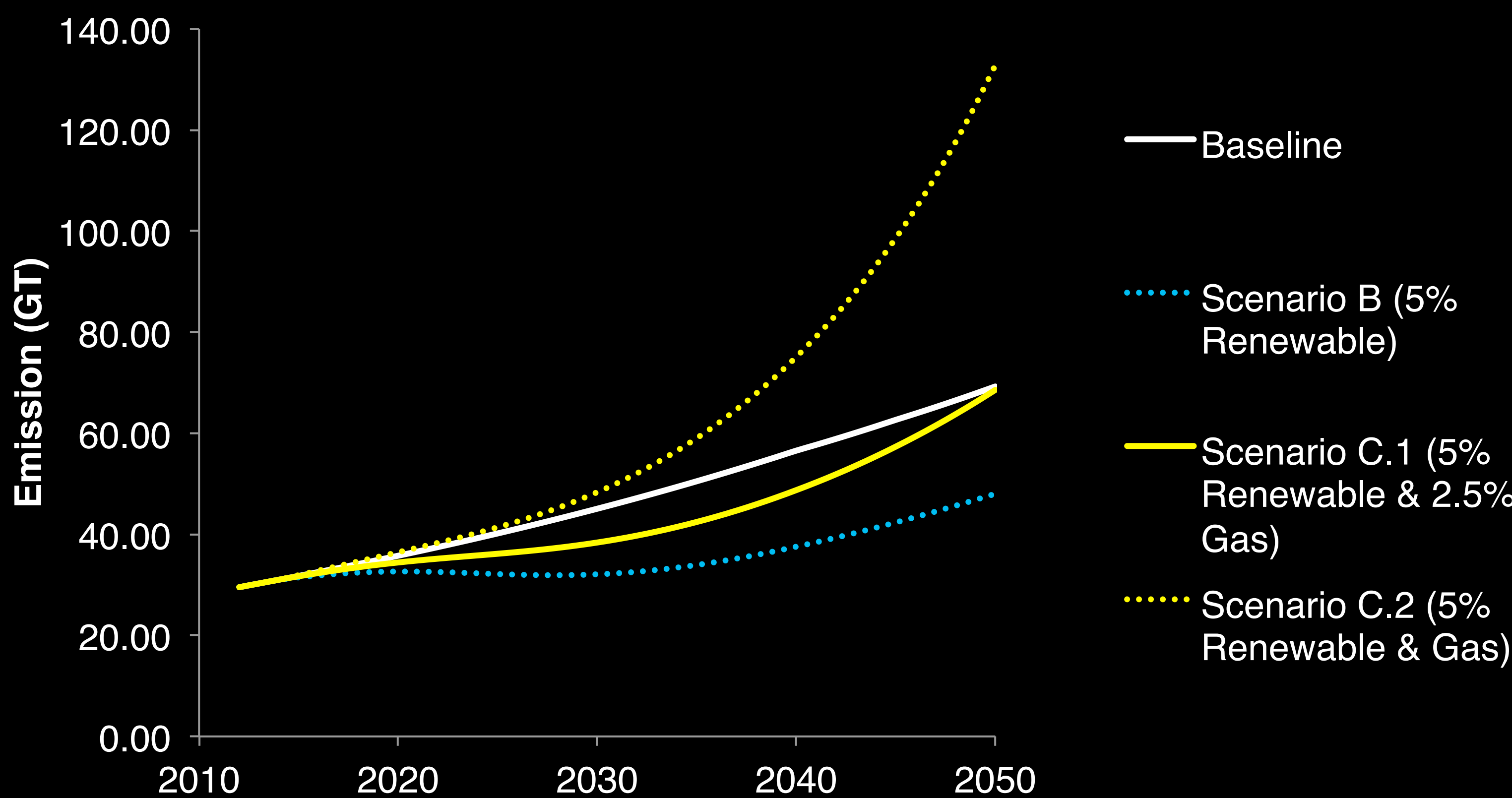
Gas' Proven Reserved to Production Ratio



Source: Author re-estimation from British Petroleum Database (2018)

IV. SCENARIO C (RECENT DEVELOPMENT OF GAS)

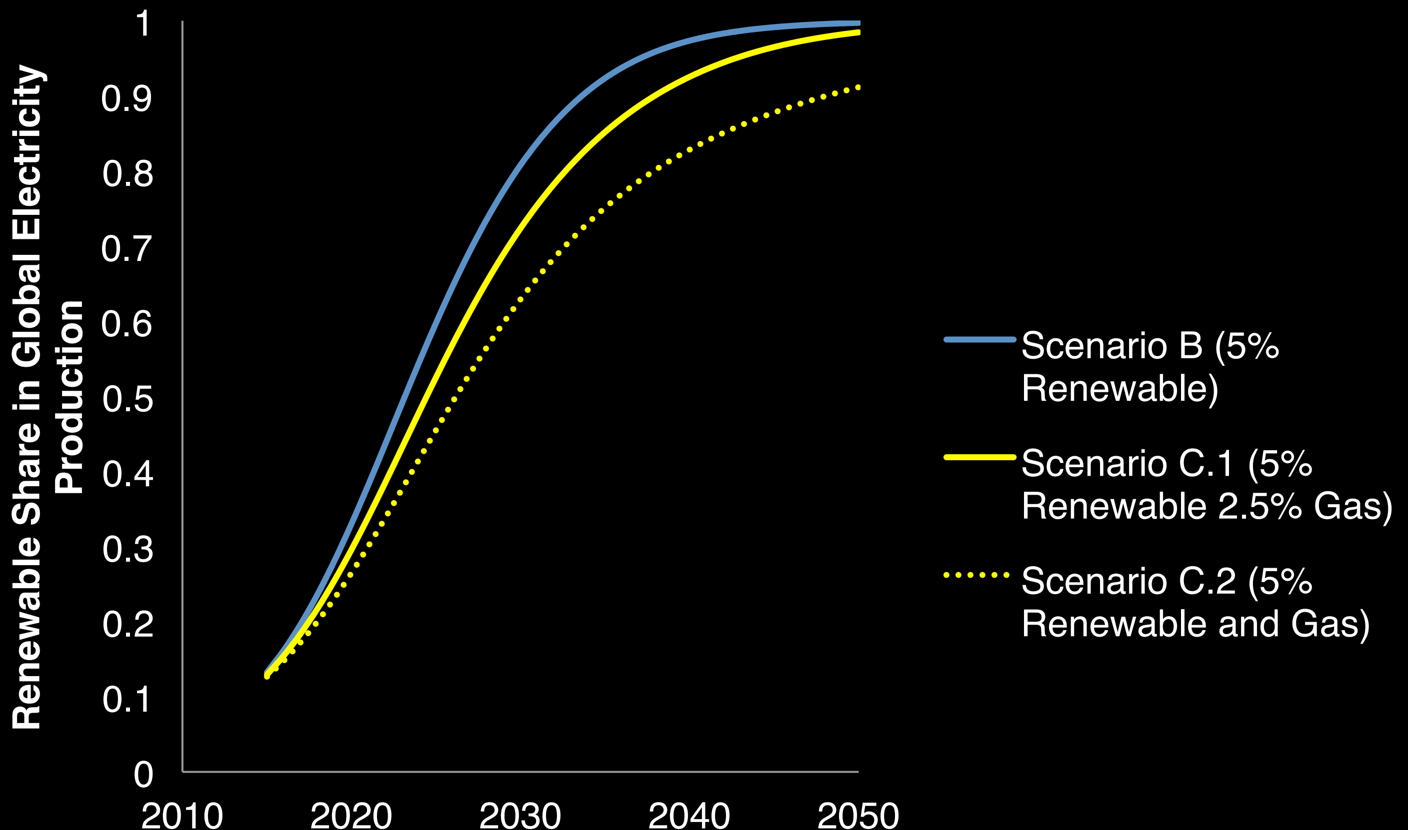
Productivity Shock on Renewable and Gas



Source: Research Estimation

IV. SCENARIO C (RECENT DEVELOPMENT OF GAS)

Renewable Share in Global Electricity Production



Source: Research Estimation

IV. SCENARIO C (RECENT DEVELOPMENT OF GAS)

- The substantial reductions on gas price will eventually affect the others fossil fuels price. The price of coal and petroleum product also declines, even as not much as the gas;
- This will be followed by more deployment of conventional fuels energy types;
- The emission will reach 68.5 GT in year 2050, closely to the same level as the baseline projection;

I. OVERVIEW/ BACKGROUND

Renewable and Emission: Global Analysis

Critics:

- **EMF 22 Models did not account for Short Run structural adjustment in Labour and Capital;**
- **GHG Emission and CO_2 Concentration Path follow Simple calculation of MAGICC 4.1 (Wigley & Rapper 2001)**