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INFLUENCES OF TRUMP'S ENERGY POLICY ON THE WORLD'S EFFORTS TO COMBAT CLIMATE CHANGE AND THEIR COSTS

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1. Introduction

In November 2015 at the 21st Conference of the Parties of the United Nations Framework on Climate Change Convention (UNFCCC), the world reached a historical turning point, the Paris Agreement, after long years of international negotiations. It aims at curbing greenhouse gas (GHG) emissions to the level of keeping the global average temperature rise below 2 degrees Celsius from before the Industrial Revolution. It took less than a year from COP21 for the agreement to enter into force, showing the high interest of the world in preventing climate change.

What drove the negotiation towards agreeing on the "2 degrees target" was the change in a way many countries and their business leaders perceive climate change mitigation measures. They used to be considered as economic burden but it is becoming clear that they bring about economic, environmental, and social benefits especially in emerging economies and developing countries. For example, burning less fossil fuels reduces air pollution and utilizing renewable energy improves energy access in an economic and environmentally sound way.

The agreement is more meaningful than its predecessor, the Kyoto Protocol, in a sense that it involves all the countries in the world. Still, it is highly dependent on the degree of major emitters' commitments, which holds some uncertainties. As mentioned, emerging economies identify various benefits in GHG mitigation and thus are becoming proactive players. Many of top business leaders also see an enormous opportunities in related technologies, products, and services. On the other hand, there still remains an argument that GHG mitigation is harmful for economy especially in industrialized countries, where little potential is left to reduce GHG emissions. If this leads to a refusal of commitment to GHG mitigation by a major emitting country, it could pose a risk of failing to avoid climate change.

The risky aspect of the agreement was timely made apparent by the U.S. presidential election in November 2016. The Trump administration prioritizes the production and consumption of domestic energy resources such as coal and gas. For this purpose, the president signed the Executive Order on Energy Independence to nullify the efforts to reduce GHG emissions by the former Obama administration such as the Clean Power Plan (CPP) and regulations on mining fossil fuels. Then in June 2017, President Trump announced the withdrawal of the U.S. from the Paris Agreement.

Although the U.S. withdrawal was a shock, many of the major emitting countries – China,

India, and EU countries – made it clear that the U.S. withdrawal would not affect their commitments to reduce GHG emissions[1]. However, these countries are likely to be influenced through changes in the international flow of energy resources, leading to changes in their prices and costs of emissions reduction considering the significance of the U.S. both as energy producer and consumer. Looking into the details of how the U.S. and other countries are influenced by the U.S. withdrawal will provide implications on whether other countries would pursue reduction efforts as they stated. This research aims at doing so based on quantitative analysis on direct and indirect economic effects of the U.S. withdrawal from the Paris Agreement.

The paper is organized as follows: The second section introduces the Trump administration's energy policies, followed by the third section which explains the methodology and the three scenarios to be analyzed. The forth section discusses the simulation results for each scenario with focus on GHG emissions reduction costs and its economic impacts on the major emitting countries. The final section concludes with the policy implications for the U.S. and other major emitting countries in their efforts to combat climate change.

2. Overview

2.1 From the Kyoto Protocol to the Paris Agreement

It is not the first time that the U.S. withdraws from international efforts to curve global GHG emissions. The U.S. withdrew from the Kyoto Protocol in 2001 and a number of analyses were done to evaluate its influences. Leakage was the main concern under the Kyoto Protocol because only a limited number of countries were imposed mandatory reduction targets. Without the U.S. and China, back then the first and second largest GHG emitter, the countries with targets together comprise less than 30% of global GHG emissions[2]. Many of the analyses concluded that the U.S. withdrawal would boost the shift from emissions from the countries with reduction targets to the U.S. and other countries without targets (e.g. Hamasaki, 2002; Kuik, 2001; Paltsev, 2001). In general, evaluation on the Kyoto Protocol is that it is not an effective framework.

Different from the Kyoto Protocol, almost all the countries take part in the Paris Agreement and they are to pursue emissions GHG reduction according to the Nationally Determined Contributions (NDCs). As of June 2017, there remain more than 30 countries who have not submitted their NDCs to the UNFCCC[3]. Still, leakage is less of a problem under the Paris Agreement since all the major emitters do have NDCs with numerical targets. The main concern of the U.S. withdrawal this time is whether other countries gain or lose as a result and in what way. Clarification of this will provide implications for how other countries could compensate an unachieved emissions reduction by the U.S., and even what could bring the U.S. back to the agreement. Research has been done on the effects of imposition of carbon tariff (Böhringer,

[1] Financial Times Article on 1st June, 2017 "As Trump Exits Paris Agreement, Other Nations are Defiant" https://www.nytimes.com/2017/06/01/world/europe/climate-paris-agreement-trump-china.html Accessed 3rd June, 2017.
[2] As of 2008 when the first commitment period of the Kyoto Protocol started.
[3] UNFCCC Submitted INDCs http://www4.unfccc.int/submission%20Pages/submissions.aspx Accessed 19 June, 2017.

2017) and various combination of regional carbon tax implementation (Perdana and Tyres, 2017) to name a few.

Perception of the Paris Agreement is mixed in the U.S. According to the White Paper released in April 2016 written by the Senate Committee, the Paris Agreement is the same as the Kyoto Protocol in that it would place economic burdens on industrialized countries like the U.S. who are required of taking increasingly drastic and unrealistic measures while other major emitters like China and India are "given a free pass" because their emissions reduction targets are almost business as usual.

On the other hand, many business leaders in the U.S. including conventional energy companies supported remaining in the Paris Agreement. Still, same arguments as the Kyoto Protocol era like above have been, and will be existent in the U.S. unless how the U.S. can benefit from drastic mitigation efforts is clarified. If added a political shock, which just happened in the last presidential election, the U.S. climate policy and position in international cooperation radically changes.

2.2 Changes in the U.S. climate policy

Under Obama administration, the U.S. played an important role together with China, the largest GHG emitter, in encouraging the Paris Agreement to enter into force. As a means to meet its own reduction target, the U.S. developed a rule called the Clean Power Plan (CPP) to limit GHG emissions from power plants under the Clean Air Act, a federal law to reduce air pollution. The CPP imposes each state to reduce a certain amount of emissions from power plants, the largest source of GHG emissions in the U.S. The state wise target sums up to 32% reduction in power sector against 2005 level by 2030. Each state is given a wide range of options to meet the target both at supply and demand side, such as increasing share of low- or zero-carbon source (renewables, natural gas, and nuclear) in power generation, reducing coal-fired generation, energy efficiency, and carbon trading programs based on multi-state compacts[4].

But soon after President Trump took office, the word "climate change" disappeared from the White House website. As mentioned above, the CPP is to be reviewed and according to EPA Administrator Pruitt, there might not be a replacement rule of the CPP if it was revoked[5]. It means that there will be no regulation on emissions from power sector.

Many speculate that impact of dismantling the CPP would be rather limited since coal is already not competitive with gas (Schlesinger, 2017). A survey on utility companies[6] conducted after the presidential election shows that many of them have no plan to newly add coal-fired capacity, while they expect extended lifetime of existing power plants. EIA (2017) forecasts that

[4] Union of Concerned Scientists "The Clean Power Plan: A Climate Game Changer" http://www.ucsU.S.a.org/our-work/global-warming/reduce-emissions/what-is-the-clean-power-plan#.WVagCYTrNdg Accessed 1st May, 2017.

[5] https://morningconsult.com/2017/05/24/pruitt-unsure-epa-will-replace-clean-power-plan/ Accessed 1st May, 2017.

[6] Utility DIVE "2017 State of the Electric Utility Survey". http://www.utilitydive.com/library/2017-state-of-the-electric-utility-survey-report/ Accessed 1st May, 2017.

coal production will increase up to 2040 without the CPP. While its real consequences are still uncertain, it will likely slow down the shift from coal to lower-emitting energy source in the U.S.

For the other countries, more of a concern is how its influence spillovers to the international efforts of mitigation. The U.S. is relatively a large player in international coal trade. The U.S. decision to review the CPP could therefore influence other countries reduction measures and their costs.

2.3 Drastic mitigation measure: coal phase-out

For each country's efforts to reduce GHG emissions, coal involves a great uncertainty especially in emerging economies and developing countries, where the rapid economic growth is heavily dependent on coal consumption. It will be a key to the success of the Paris Agreement whether a shift from coal is realized and if so how early it progresses.

China, despite its high dependency on coal, is moving toward a direction of reducing coal consumption most importantly for the purpose of mitigating air pollution. According to IEA (2016), China's coal consumption might have already peaked in 2013. The National Development and Reform Commission (NDRC) anticipates that the country will burn around 4.1 billion tons of coal in 2020 compared to 3.96 billion tons 2016[7]. Based on these forecasts, it is likely that China's coal consumption will at least flatten.

Some of the industrialized countries who are currently large consumers of coal have made their attitude toward coal explicit by announcing coal phase out plan within a decade. The United Kingdom (UK) and France have decided to completely remove coal from their power generation, with the UK targeting at 2025[8] and France 2023[9]. Canada, under the current Trudeau administration, has decided to phase out coal as well. It announced in November 2016 that it would phase out coal-fired electricity by 2030[10].

Although other countries have not made explicit their attitude toward coal, they cannot be intact from policies of important players in both the world's coal trading and GHG mitigation efforts.

With the prospect of strengthening regulations on carbon, it is also becoming common especially among industrialized countries that investing or involving in coal-fired power plants is a risky business. In most of emerging economies and developing countries, however, coal will stay as the main source of energy at least for a short- to mid-term even under the Paris Agreement, for it is the most affordable and easily accessible energy source in those countries. How the coal

[7] Mining.com Article on 4th January, 2017. http://www.mining.com/china-steps-up-efforts-to-cut-coal-capacity/ Accessed 1st June, 2017.

[8] Carbon Brief Article on 9th November, 2016. https://www.carbonbrief.org/uKyoto Protocollans-to-close-last-coal-plant-by-2025 Accessed 1st June, 2017.

[9] Independent Article on 17th November, 2016. http://www.independent.co.uk/news/world/europe/france-close-coal-plants-shut-down-2023-global-warming-climate-change-a7422966.html Accessed 1st June, 2017.

[10] The Guardian on 21st Nov, 2016 https://www.theguardian.com/world/2016/nov/21/canada-coal-electricity-phase-out-2030 Accessed 1st June, 2017.

phase-out plan by early moving countries progresses from this point on and how it influences the global GHG mitigation should be carefully observed.

3. Methodology

3.1 GTAP-E and database

GTAP-E Version 6-pre2 (2007) is employed for the analyses. GTAP-E is energy and environmental version of Global Trade Analysis Project (GTAP) model. GTAP-E incorporated CO2 emissions from combustion of fossil fuels as well as an energy substitution structure in the standard GTAP model. The database used is GTAP Database Version 9, 2011 and regions and sectors are aggregated to 19 countries/regions and 15 sectors (see Appendix).

Since analyses are to be conducted regarding 2030, which most of the countries set their NDC for, the database is updated to 2030 by giving exogenous figures to population, labor, and capital to approximate the economic balance of each country and region in 2030. Simulation for each scenario is conducted on the result calculated from the baseline update simulation and then is compared with each other.

3.2 CO2 emissions reduction target

Since GTAP-E only tracks CO2 emissions from energy consumption, the part of the NDCs which depend on reduction of energy consumption needs to be identified for this analysis. Climate Action Tracker (CAT) evaluates a number of NDCs which have various base year and/or unit of emissions reductions[11]. CAT translates each country's NDC into the one which is a percentage reduction compared to 1990 as a common base year. CAT also excludes LULUCF from the targeted reduction figures since emissions from land use change involve a lot of uncertainties. Therefore, targets recalculated by CAT are considered as appropriate for this analysis which focuses on CO2 emissions from energy consumption. Table 1 shows NDCs of major emitters and the figures recalculated by CAT.

There are countries which do not describe clear reduction targets or with targets which only keep emissions at BAU level. For those, CO2 emissions are still exogenous and are given the value of zero so that their emissions do not exceed the baseline. Regarding a target with a certain range, the lower end of it is used for the analysis.

Emission reduction target figures are recalculated based on the original NDCs or, for those countries which include emissions reduction related to land use change, the figures by CAT with 1990 as the base year. Energy related CO2 emission growth figure from 1990-2030[12] is also used for the recalculation. Table 1 shows the recalculated figures for each country/region.

[11] Climate Action Tracker http://climateactiontracker.org/indcs.html
[12] EIA (2017).

Table 1 Recalculated figures of CO2 emissions reduction target (%) for each country/region

USA	MEX	CAN	CHN	JPN	KOR	IDN	IND	RUS	AUS	BRA	LSA
-16.0	-4.4	-22.0	-23.0	-26.0	-12.3	-11.2	-8.0	0	-45.0	-19.0	0

DEU	GBR	FRA	EU25	MENA	SSA	ROW
-42.4	-42.4	-42.4	-42.4	0	0	0

3.3 Scenarios to be analyzed

Analysis is conducted regarding the following scenarios;

1) Paris Agreement: all the countries achieve CO2 emissions reduction based on their NDCs.
2) U.S. withdrawal: the U.S. withdraws from the Paris Agreement and does not comply with its reduction target. It is assumed that no leakage occurs by exogenizing each country/region's CO2 emissions.
3) U.S. withdrawal and coal phase-out: the U.S. withdraws from the Paris Agreement and some countries complete their coal phase-out plan by 2030. It is assumed that there is no coal input in power generation in 2030 in these three countries.

4. Results and discussions

4.1 Scenario1: Paris Agreement

Percentage of emissions reduction compared to the baseline is the same as the exogenous reduction target figures recalculated based on their NDCs in Table 1. Carbon tax price needed to achieve the target figures is calculated (Table 2). An extremely high price is observed in European countries, Japan, and Australia which have the relatively high target figures (see Table 1). In addition to the level of targets, limitation of available reduction measures in the methodology causes rather high carbon tax rates of these countries. The measures are either reducing production or substitution between capital and energy as well as among energy sources, which comprises only of fossil fuels.

Table 2 Real carbon tax rate (USD)

USA	MEX	CAN	CHN	JPN	KOR	IDN	IND	RUS	AUS	BRA	LSA
28.1	9.2	46.7	14.3	143.5	33.2	28.6	1.5	5.2	188.4	87.9	1.4

DEU	GBR	FRA	EU25	MENA	SSA	ROW
233.7	252.3	442.4	294.3	2.7	1.9	6.3

Table 3 shows real GDP change, its breakdown and percentage change of GDP of each country/region. Other than the countries/regions with zero reduction targets, India's economy hardly gets affected, meaning that its NDC is not stringent. The U.S., despite its assertion that the

Paris Agreement is more harmful to its economy than that of emerging economies, turns out to have less stringent target even compared with some emerging economies like China, Mexico, and Brazil with a relatively small negative impact of -0.13% on its GDP. European countries suffer from the largest economic loss in the world.

Table 3 Real GDP change and its breakdown (USD million), and percentage change of GDP under the Paris Agreement compared to the baseline

	Consumption	Investment	Export	Import[13]	Total	% change
USA	-9,206	-75	-29,721	17,478	-21,524	-0.13
MEX	-5,447	-1,735	1,276	2,516	-3,391	-0.21
CAN	-8,790	-2,045	1,356	4,356	-5,123	-0.25
CHN	-2,389	-11,301	-18,509	8,352	-23,847	-0.29
JPN	-16,235	3,659	-82,087	55,663	-39,000	-0.81
KOR	3,862	1,125	-15,176	8,602	-1,586	-0.10
IDN	-1,925	-845	-1,666	3,558	-879	-0.07
IND	5,330	-60	-895	-3,476	899	0.06
RUS	-39,149	-7,512	-6,791	31,269	-22,184	-0.98
AUS	-16,957	-3,520	-9,593	14,190	-15,880	-1.07
BRA	-4,108	-492	-7,168	5,373	-6,396	-0.17
LSA	-8,623	-2,712	4,023	6,474	-838	0.00
DEU	-41,478	-1,031	-81,840	64,179	-60,170	-1.82
GBR	-36,654	-1,427	-37,686	37,396	-38,372	-1.58
FRA	-38,604	4	-67,005	48,455	-57,150	-2.16
EU25	-134,529	-741	-324,534	251,684	-208,120	-2.48
MENA	-56,156	-20,298	19,438	51,617	-5,399	-0.04
SSA	-15,128	-4,493	5,731	11,812	-2,077	-0.05
ROW	-20,984	-19,210	25,551	8,067	-6,577	-0.04
Total	-447,172	-72,710	-625,296	627,564	-517,614	-0.13

GDP in almost all the countries negatively changes. When its breakdown is observed, import in total is decreased (positive change in the total GDP change) in all the countries except India primarily due to a drop in production to curb emissions, which depresses firms' demand for intermediate. Regarding fossil fuels, import increases in those countries with low reduction targets because price rise of the composite (domestic and import from each country/region combined) of each fossil fuel is relatively higher than imported one. In those with relatively stringent targets such as Japan, European countries, Australia, and Brazil, imports of fossil fuels decrease since price rise of imported fossil fuels as intermediate is higher than that of their composite. This tendency comes from the fact that the demand for fossil fuels shrinks more significantly in those countries with stringent targets and so the domestic price is relatively lower than import price, which reflects the price of other countries where demand drops less

[13] Positive figures indicate decrease in import, and negative figures indicate increase in import.

significantly. Energy exporting countries such as Middle East, African countries, and Russian Federation, reduce their export of fossil fuels, while increase that of manufactured goods with which they gain competitiveness due to a very low carbon tax.

With regard to export, Mexico, Canada, and Latin and South America, all an important trade partner of the U.S., increase export in such sectors as heavy manufacturing, chemicals, and motor vehicles[14] especially to the U.S. due to their relatively low carbon tax. They are more competitive in export of heavy manufacturing goods than China, which has, as its intermediate, relatively high share of heavy manufacturing goods strongly influenced by carbon tax in and out of the country. Exports of European countries shrink a lot because of their high carbon tax.

Regarding consumption, European countries are severely affected since carbon tax gets reflected to consumption price. But those regions with a very low carbon tax such as Russian Federation and Middle East also experience a large decline in consumption. In these regions, influence of consumption price rise is much smaller than others, while per capita income falls due to a price drop in production factors, which leads to decreased private demand.

In countries with targets beyond keeping a baseline, lowering carbon intensity of energy takes place by substituting more carbon intensive energy with the one less so (see Table 4), such as oil and gas with oil products, coal with non-coal (composite of oil, gas, and oil products). Substitution between non-electricity and electricity takes place depending on emission intensity of electricity in each country to form energy composite, which is then substituted with capital. But any of this substitution effect does not exceed the reduction in overall firm's demand. Substitution also happens among inputs for electricity production by substituting capital-energy composite with labor. However, this substitution is not realistic and what instead would happen is further decrease of electricity production than the results of this analysis.

[14] Export of motor vehicles to the U.S. increases only from Canada.

Table 4 Emission intensity of each energy products by country and region

	coal	gas	oil	oil_pcts
USA	0.37	0.19	0.09	0.04
MEX	0.49	0.18	0.19	0.06
CAN	0.39	0.22	0.07	0.04
CHN	0.52	0.46	0.15	0.04
JPN	0.21	0.06	0.09	0.02
KOR	0.41	0.05	0.08	0.03
IDN	0.41	0.14	0.09	0.04
IND	1.11	0.12	0.10	0.03
RUS	0.40	0.10	0.07	0.03
AUS	0.27	0.10	0.05	0.03
BRA	0.27	0.23	0.10	0.04
LSA	0.39	0.41	0.08	0.05
DEU	0.22	0.07	0.08	0.01
GBR	0.23	0.10	0.08	0.02
FRA	0.22	0.09	0.11	0.02
EU25	0.31	0.07	0.08	0.02
MENA	0.33	0.21	0.14	0.05
SSA	0.62	0.23	0.14	0.03
ROW	0.42	0.11	0.11	0.03

4.2 Scenario 2: U.S. withdrawal from the Paris Agreement

If the U.S. removes its reduction target while all the others achieve theirs, the U.S. CO2 emissions increase by about 18% compared to the case of target achievement. In addition to the unachieved reduction of 16% based on its NDC, the emissions further expand by 2%.

This additional increase is mainly due to increased demand for coal, gas, and oil products. Demand for oil products increases both as intermediate by firms and as a final product for consumption, making oil products the largest contributor of the additional emission increase in the U.S. Demand for coal, gas, and oil expands with regard to both domestic and imported one, but the percentage of increase is larger for imported ones since their price fall due to decreased demand for fossil fuels in other countries to meet their reduction targets. However, increase in demand for, or in emissions from, domestic coal and gas is larger because dependence on import is originally small for coal and gas in the U.S. Emission from oil in the U.S. is originally very small and does not change much. Regarding oil products, demand expands particularly for domestic ones due to price drop in imported oil, which accounts for nearly 60% of intermediate of oil products.

Regarding GDP, an additional 0.02% expansion is observed in the U.S. on top of the avoided loss under the Paris Agreement which is -0.13%. The additional gain comes from positive changes in private consumption especially of oil products, transport, and gas. The reason for expanded demand for oil products and gas is explained above. Demand for transport also

expands due to the fact that oil products is its main intermediate. The U.S. export increases in manufacturing due to the elimination of its carbon price as well as to the lower price of imported fossil fuels used as intermediate. Although the U.S. total export increases, it loses competitiveness as an energy exporter with its supply prices of fossil fuels relatively higher in the world since its energy demand is not suppressed by emissions cap.

In all the other countries/regions, carbon tax falls slightly because of the U.S. export prices of coal, gas, and oil rise by its increased domestic demand in the U.S. Imposition of costs of carbon emissions on fossil fuels is lessened by the impact of their market price rise in an influential country in energy market.

Table 5 Change in real carbon tax (USD) from Scenario 1 to 2

USA	MEX	CAN	CHN	JPN	KOR	IDN	IND	RUS	AUS	BRA
-28.10	-0.43	-1.32	-0.05	-1.74	-0.69	-0.50	-0.00	-0.38	-0.77	-1.33

LSA	DEU	GBR	FRA	EU25	MENA	SSA	ROW
-0.12	-2.07	-2.00	-3.82	-2.50	-0.20	-0.17	-0.39

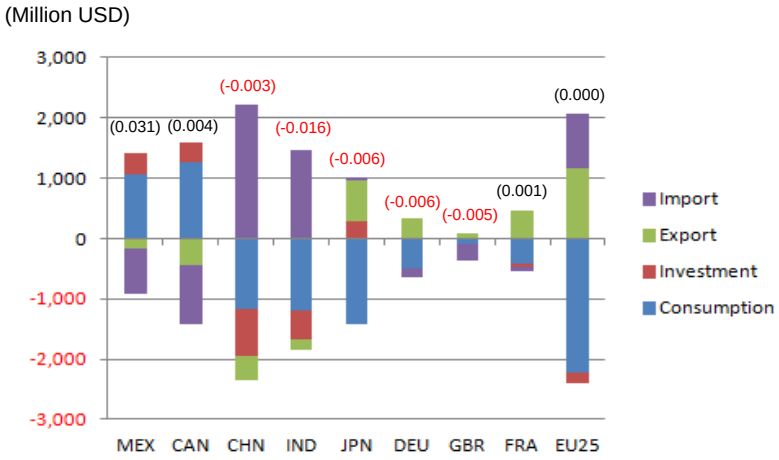
Table 6 Percent changes in supply price of energy products from the U.S. to other countries/regions

	MEX	CAN	CHN	JPN	KOR	IDN	IND	RUS	AUS	BRA	LSA	DEU	GBR
coal	1.49	1.29	1.26	1.34	1.29	1.29	1.48	1.32	1.33	1.33	1.32	1.29	1.39
gas	3.14	2.94	2.94	2.97	2.98	3.02	3.14	3.14	3.14	3.14	2.95	3.14	3.14
oil	1.64	1.41	1.57	1.64	1.64	1.64	1.39	1.64	1.64	1.58	1.64	1.63	1.64
oil_pcts	0.03	0.02	0.02	0.01	-0.00	0.02	0.02	0.00	0.01	-0.00	-0.01	0.02	0.03

	FRA	EU25	MENA	SSA	ROW
coal	1.39	1.38	1.32	1.33	1.41
gas	3.14	3.14	3.14	3.14	3.14
oil	1.64	1.61	1.58	1.64	1.59
oil_pcts	0.03	-0.00	-0.00	0.02	0.02

GDP changes from Scenario 1 are very small, with less than positive or minus 0.01% in most of the countries. Though the changes are almost negligible, how the U.S. withdrawal influences other countries/regions can be observed from its breakdown (Figure 1).

Figure 1 Breakdown of changes in real GDP from Scenario 1 to 2



*The figures in brackets indicate percentage change in real GDP from Scenario 1 to 2.

Mexico and Canada see a slight improvement in their GDP compared to Scenario 1 from increased consumption and investment, which exceeds the negative change in trading. Export of coal, oil, and oil products from these countries to the U.S. increases as well as from other energy exporting countries such as Middle East, Africa, and Russian Federation to meet expanded demand for these fossil fuels in the U.S. Due to the influences of expanded production of fossil fuels, prices of production factors, or labor and capital in Mexico and Canada, do not fall as much as other countries, which leads to an increase in private demand through a relatively small drop in per capita income.

Regarding China and India, consumption, investment, and export decreases leading to negative changes in their GDP, which are largely mitigated by decrease in import. Import of fossil fuels, especially oil, decreases a lot in these two countries because their firm's demand for imported oil as intermediate shrinks more than most of the other countries. It comes from the fact that China and India are significantly affected by the U.S. withdrawal in terms of exports of manufactured goods, and that their domestic price of oil does not rise as much as imported one.

In Japan, decrease in consumption is a single cause of negative change in its GDP while the positive changes are from increased investment and export, and decrease in import. Private demand shrinks due to a decline in per capita income. Its export of manufactured goods in such sectors as motor vehicles and heavy manufacturing increases because of the drop in the firm's price of imported fossil fuels except oil products as intermediate. While the market price of imported fossil fuels rises, the fall in carbon tax in Japan by about $2 overweighs its influence.

European countries also benefit from the drop in their carbon tax and increase export of manufactured goods. However, negative changes take place in their consumption, investment, and import. Private demand shrinks by the influences of a drop in per capita income which

overweigh the positive change by fall in consumption prices in Germany, France, and other European countries. The UK is an exception with its per capita income does not fall as much as other European countries because of its expanded production of oil, which also leads to an increase of investment only in the UK among European countries.

4.3 Scenario3: U.S. withdrawal and coal phase-out

Influences of coal phase-out in power generation by earlier than 2030 by Canada, the UK and France under the situation where the U.S. withdraws from the Paris Agreement are analyzed. For the analysis, the result from Scenario 3 simulation is compared with that of Scenario 2 simulation.

Canada, the UK and France experience negative changes in GDP while there is almost no influence on other countries (Table 7). In these three countries, consumption and investment decreases and so does the export in addition in France. Private demand falls particularly for electricity and services, due to a sharp price rise for the former and drop in per capita income for the latter. Since coal cannot be used as an input for electricity generation, it is substituted with more costly fossil fuels and capital, leading to rise in market price of electricity by about 386% in Canada, 609% in the UK, and 128% in France. The extent of price rise in France is much smaller than other two countries because it is originally less dependent on coal for electricity generation. For the same reason, negative change in GDP of France is smaller than other two coal phase-out countries.

This significant price rise of electricity leads to its increased import in these three countries. Import of oil in Canada and France, and oil products and minerals in the UK and France also increases while export drops in all the other sectors, leading to decrease in total imports of these countries. Decrease in their imports except electricity and some of the fossil fuels are mainly caused by the fact that firm's demand for products as intermediate shrinks.

The UK and Canada meet its increased demand for oil by expanding the domestic production. The UK also increases its production of gas to be exported as a result of its improved competitiveness in gas export since the price of its production factors drops, which lowered the pas price of the UK as well.

Table 7 Changes in real GDP (%) from Scenario 2 to 3

USA	MEX	CAN	CHN	JPN	KOR	IDN	IND	RUS	AUS	BRA
0.004	0.001	-4.163	0.002	0.004	-0.006	0.001	0.002	0.031	-0.002	0.000

LSA	DEU	GBR	FRA	EU25	MENA	SSA	ROW
0.000	-0.016	-4.376	-1.754	-0.015	0.003	0.005	0.016

In the countries/regions other than coal phase-out countries, the market price of coal rises because its supply shrinks responding to a drop in demand for coal. In Canada and the UK, coal price falls due to their extent of dependency on domestic coal which is strong enough to make the impacts of price fall in domestic coal overweigh the rise of imported one. France is different from other coal phase-out countries, with its market price of coal rises. It is because of its high dependency –over 90%– on imported coal in almost all the sectors including electricity. In addition, the shift away from coal is not as significant as Canada and the UK. The market price of other fossil fuels –oil, oil products, and gas– rises in almost all the countries due to the substitution of coal with these fuels.

Table 8 Percent changes in market price of energy products from Scenario 2 to 3

	coal	oil	oil products	gas	electricity
USA	0.81	0.62	0.62	1.34	0.71
MEX	0.47	0.61	0.64	1.05	0.82
CAN	-0.75	0.40	0.52	4.18	385.88
CHN	0.67	0.61	0.62	0.74	0.94
JPN	0.57	0.60	0.62	0.63	0.86
KOR	0.52	0.63	0.60	0.67	0.75
IDN	0.67	0.61	0.62	0.74	0.79
IND	0.41	0.61	0.59	0.65	0.50
RUS	0.42	0.58	0.61	0.68	1.10
AUS	0.53	0.57	0.61	0.72	0.91
BRA	0.53	0.58	0.60	0.74	0.63
LSA	-0.18	0.62	0.59	0.93	0.69
DEU	0.60	0.42	0.59	0.63	1.43
GBR	-33.62	-1.10	4.86	-6.88	609.35
FRA	4.91	1.18	0.64	3.81	128.23
EU25	0.74	0.49	0.75	0.65	1.49
MENA	0.54	0.62	0.62	0.75	0.77
SSA	0.61	0.60	0.66	1.03	1.99
ROW	0.72	0.55	0.67	0.74	1.64

Carbon tax falls in coal phase-out countries because they are enforced to substitute coal for power generation with non-coal fossil fuels, which are more expensive and less carbon intensive than coal. It lessens the need for imposing carbon tax which encourages the shift away from carbon intensive fossil fuels to the ones less so. Carbon tax rises in all the other countries and regions except Mexico as a result of price fall of coal and oil.

Table 9 Changes in carbon tax from Scenario 2 to 3 (USD)

MEX	CAN	CHN	JPN	KOR	IDN	IND	RUS	AUS	BRA	LSA	DEU	GBR
-0.36	-24.54	0.14	0.48	0.13	0.03	0.04	0.70	0.14	0.19	0.36	3.73	-129.83

FRA	EU25	MENA	SSA	ROW
-35.62	6.59	0.29	1.22	2.56

5. Next steps

Although the methodology used in this research analyzes the impacts of the U.S. withdrawal and coal phase-out policy through international trading of energy commodities and other goods, there are some limitations. Two points particularly important for this analysis are as follows. Firstly, no consideration of possibility to supply enough energy commodities is included. When coal is not an option in one of the analysis, it is assumed in the model that the other energy commodities to which demand shift significantly can be supplied, which is unlikely the case in reality. Secondly, options to reduce emissions are limited to substitution among fossil fuels, between fossil fuels and electricity, and between energy composite and capital. Despite the fact that zero-carbon energy source such as solar and wind plays an ever more important role, this model does not explicitly shows the changes in such energy source as a result of emissions reduction.

Therefore, analyses done in this research, especially the one on coal phase-out impacts under the Paris Agreement should be done under the assumption which better reflects the recent trends of energy system all around the world. That is, renewable energy is strengthening its presence in electricity generation and its cost declining quickly. So the following question is to be pursued in the future research; if the renewable and its rapid cost reduction are included to reflect the dynamic changes in energy system observed in recent years, how would the results change? For this, a CGE model which incorporates more detailed electricity generation sources including renewables should be sought. In addition, analysis by a dynamic CGE model should also be pursued to reflect the impacts of capital accumulation on the next year's investment, year-on-year technological improvement in electricity generation especially of renewables.

6. Conclusion

To seek a condition which prevents any other major emitting country to withdraw from the Paris Agreement in the future, it needs to be clear how each country will be influenced by its own or other major emitter's withdrawal. The overall results of analysis shows that the U.S. is rightly incentivized to withdraw from the Paris Agreement, but by looking into details, some of the influences might not necessarily encourage the withdrawal. The analysis showed that the U.S. expands its demand for imported coal with all the other countries commit to reducing emissions and therefore the price falls outside the U.S. Also, the U.S. loses its competitiveness as an energy exporter since its market price of energy rises due to expanded demand. Still, these may not significant enough to prevent the U.S. from withdrawal. For other countries, economic impacts from achieving their emission reduction targets do not change a lot as a result of the U.S. withdrawal from the Paris Agreement. Therefore, it is more important for the agreement whether each of the major emitting country can keep on track to meet its target rather than whether the U.S. gets back to making commitment to emissions reduction. A drastic measure like coal phase-out by just a few countries also does not provide a strong influence on the U.S. However, significant changes in energy system – rapid cost reduction and technological improvements leading to unprecedented growth of renewable energy– may bring about different results. Further researches should pursue what would make commitments to decarbonization beneficial under the dynamically changing energy system.

Appendix: Aggregation of regions and sectors

Aggregated region	Countries included
USA	United States of America
MEX	Mexico
CAN	Canada
CHN	China
JPN	Japan
KOR	Korea
IND	India
IDN	Indonesia
RUS	Russian Federation
AUS	Australia
BRA	Brazil
LSA	Countries in Latin and South America except Mexico and Brazil
DEU	Germany
GBR	United Kingdom
FRA	France
EU25	Countries in European Union except Germany, UK, and France
MENA	Countries in Middle East and North Africa
SSA	Sub Saharan African Countries
ROW	Rest of the world

Aggregated sector	Sectors included
agr	Agricultural products, food products, forestry, fishery
coal	Coal
gas	Gas extraction and distribution
oil	Oil
min	Minerals, mineral products
texp	Textiles, wearing apparel
oil_pcts	Petroleum, coal products
crp	Chemical, rubber, plastic products
mvh	Motor vehicles and parts
hmfg	Machinery, electronic equipment, metals
lmfg	Leather products, wood products , paper products, metal products
trp	Transportation
electricity	Electricity
cns	Construction
ser	Services

References

C. Böhringer, T. Rutherford (2017) “Paris After Trump: Carbon Tariffs Reloaded”, 2017 GTAP Conference Paper, (https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=5339) Accessed 20th June, 2017.

O. Kuik (2001) “The Effect of Trade Liberalization on Carbon Leak-age under the Kyoto Protocol: Experiments with GTAP-E”, 2001 GTAP Conference Paper, (https://www.gtap.agecon.purdue.edu/resources/download/261.pdf) Accessed 1st June, 2017.

H. Hamasaki (2002) “The Economic and Environmental Impact of the US Withdrawal from the Kyoto Protocol”, 2002 GTAP Conference Paper, (https://www.gtap.agecon.purdue.edu/resources/download/1179.pdf) Accessed 1st June, 2017.

International Energy Agency (IEA) (2016) Medium-Term Coal Market Report 2016.

S. Paltsev (2001) “The Kyoto Protocol: Regional and Sectoral Contributions to the Carbon Leakage”, The Energy Journal, Vol. 22, No. 4, pp53-79.

S. Perdana, R. Tyres (2017) “Global Climate Change Mitigation: Strategic Interactions or Unilateral Gains?”, 2017 IAEE International Conference Paper, (www.iaee.org/iaee2017/submissions/ExtendedAbs/Sigit%20Perdana.pdf) Accessed 20th June, 2017.

B. Schlesinger (2017) “Energy Policy in the Trump Administration”, IAEE Energy Forum, Second Quarter 2017, pp5-7.

J. Burniaux and T. Truong (2007) “GTAP-E: An Energy-Environmental Version of the GTAP Model”. GTAP Technical Paper No.16.

U.S. Energy Information Administration (EIA) (2017) 2017 Annual Energy Outlook.

U.S. Senate Environment and Public Works (EPW) Committee (2016) “Lessons from Kyoto: Paris Agreement Will Fail National Economies and the Climate” Majority Staff White Paper.