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*"Accelerating Economic Transformation, Diversification and Job  
 Creation (Virtual Conference)"*



## United States Re-enters the 2015 Paris Climate Agreement: The Unexpected Twists and the Opportunity Costs? A CGE Approach

**Kitetu, Geoffrey Musyoki**  
**Ko, Jong-Hwan**

Division of International and Area Studies  
 The Graduate School, Pukyong National University

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## Introduction

- Discussion about the impact of climate change remains an ongoing debate *due to its dynamic nature and the interlinkage between human activities and greenhouse gas emissions*.
- In this preliminary study, we employ a static GTAP-E model to evaluate the ripple effects of carbon emission on the global economy, including the opportunity cost the USA is likely to pay to implement its nationally determined (NDC) targets.



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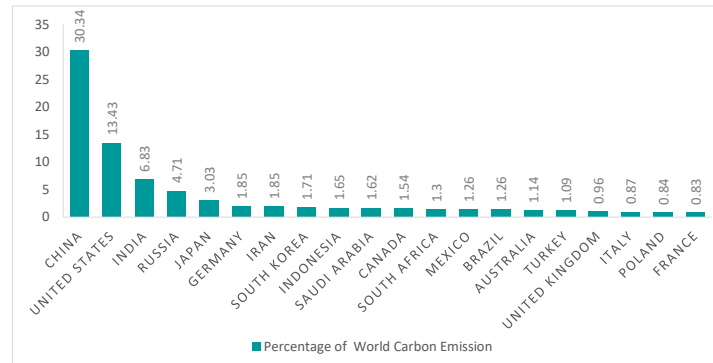
## Background - Paris Climate Agreement of 2015 (COP26)

- In 2015, the United Nations Framework Convention on Climate Change (UNFCCC) parties agreed in Paris to limit global temperature rise to less than 1.5°C above pre-industrial levels to avoid the worst effects of climate change. [UNFCCC \(2021\)](#)
- Global CO<sub>2</sub> emissions will have to decline by 45% from 2010 levels by 2030 and reach net-zero by around 2050 to avoid temperature rise beyond 1.5°C. [IPCC \(2018\)](#) Special Report: Global Warming of 1.5°C.

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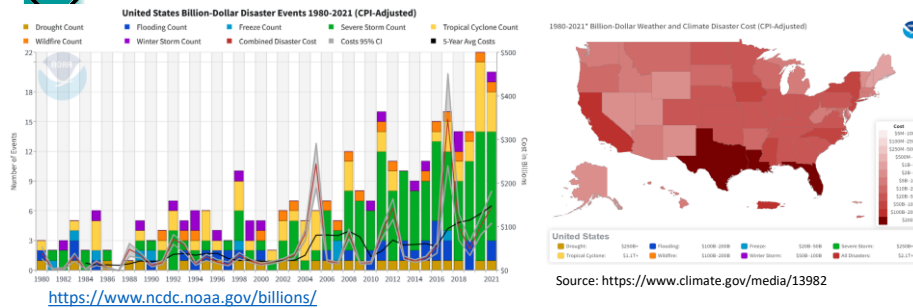
**Table 1. World Share Of  $CO_2$  Emission (2015) by Country in Percent**



Source: <https://worldpopulationreview.com/country-rankings/co2-emissions-by-country>

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## Cost of Weather and Climate Disasters



- Historical data from 1980 - 2021 show that the USA has face numerous climate disasters worth billions of dollars
- disaster type (colors), frequency (left-hand vertical axis), and cost (right-hand vertical axis).
- *The number and cost of weather and climate disasters is rising*
- *In addition to human life, these climatic disasters lead to billion-dollar losses*

*Syed, and Ullah (2021) argues that social cost of  $CO_2$  is likely more than estimated In their study Bohringer and Rutherford (2017) alludes that the cost of implementing the NDC targets by the USA is likely lower than retaliatory taxes on imports from USA*

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## A Summary of COP26 Conference Deliberations

- A raft of measures focusing on mitigation, adaptation, finance, and collaboration, which aim at limiting the rise in global temperature to 1.5C, were agreed upon.

*The COP26 pact secured near-global net-zero GHG emission reduction targets:*

- new NDCs from 153, accounting for over 90% of world GDP.
- **Consolidated financial support from developed countries**, romped in five public finance institutions to stop international support for the unabated fossil fuel energy sector in 2022 -secured.
- An undertaking by private financial institutions and central banks to realign their financial policies towards global net-zero GHG emission reduction target.

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## COP26 Conference Deliberations

- **Consolidation of collaborative** efforts between governments, businesses, and civil society on the delivery of climate goals faster.
- **Unified efforts**, the establishment of collaborative councils and dialogues in energy, electric vehicles, shipping, and commodities.

### **Streamlining of the Paris Rulebook**

- *agreeing on the 'enhanced transparency framework* (standard reporting of emissions and support),
- a new mechanism and standards for international carbon markets, and
- set timeframes for emissions reduction targets were actualized (UNFCCC 2021).

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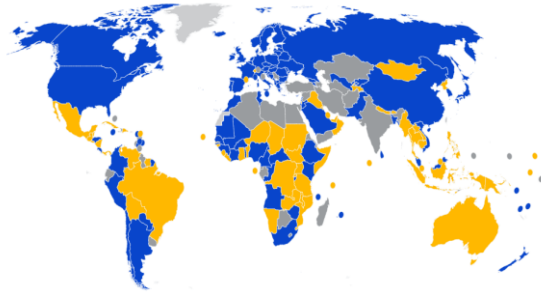


## Updated NDC (COP26)



- 159 countries (83.6% of global emissions) have submitted a new or updated NDC
- 94 of the 159 countries (65.4% of global emissions) have submitted a new or updated NDC with reduced total emissions compared to their previous NDC

- Submitted New or Updated NDC with Reduced Total Emissions
- Submitted New or Updated NDC
- Not Applicable
- No Information



Source: <https://www.climatewatchdata.org/2020-ndc-tracker>

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## Study Objectives



- on November 4, 2020, the United States of America (USA), formally exited the Paris Climate Agreement.
- On January 27, 2021, President Joe Biden signed an executive order commencing a 30-day process to rejoin the Paris Agreement on climate change.
- On February 19, 2021, the United States officially rejoins the Paris Agreement on climate

### Donald Trump withdraws US from Paris climate accord

Withdrawal from 2016 agreement, in line with president's election campaign promise, could take up to four years.



Trump has inspired Republican supporters for expected blowback (AP)

9 Jun 2017

The US is withdrawing from the Paris agreement on climate change. President Donald Trump has announced at a White House Rose Garden speech.

*in a twist of events,*

### Biden signs executive order rejoining Paris climate agreement

BY PTI PUBLISHED: PUBLISHED DATE: 12:52 PM THU / 21 JANUARY 21



U.S. President Joe Biden prepares to sign a series of executive orders at the Resolute Desk in the Oval Office just hours after his inauguration in Washington, DC. The first order committed the US and 121 other countries to keeping strong global temperature below 2C above pre-industrial levels.

Source: <https://telanganatoday.com/biden-signs-executive-order-rejoining-paris-climate-agreement>

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## Study background

- The USA government submitted a second NDC roadmap to reduce GHG emissions on April 22, 2021, and a long-term low GHG development strategy on November 1, 2021 (Fenhann 2022, and UNEP, 2022).
- A review of existing literature identifies numerous studies evaluating the potential impact of the reduction of CO<sub>2</sub> emissions by the USA on its economy, which includeBohringer and Rutherford (2017); Lee, Chang, and Lee, 2013; Jenkins, 2014; Rivers and Schaufele, 2015; Herrnsstadt and Dinan, 2020; van de Ven, Westphal, González-Eguino, Gambhir, Peters, Sogannaes, et al., 2021).
- Significantly, *the model and data applied in these studies, including regional and sectoral aggregation, are different from those employed in this study.*
- Furthermore, *the assumptions on reduction targets of CO<sub>2</sub> emissions made by (Bohringer and Rutherford (2017); Jenkins 2014, Lee, Chang, and Lee, 2013; Rivers and Schaufele, 2015; Herrnsstadt and Dinan, 2020) are significantly different from those made in this paper.*

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## Study Objectives

- This study aims to empirically examine the potential world-wide economic impacts of reducing CO<sub>2</sub> emissions by 2030 according NDC (COP26 and Paris climate agreement) and the opportunity cost the USA is likely to pay for implementing its NDC CO<sub>2</sub> emissions reduction targets
- using a static GTAP-E multi-region, multi-sector computable general equilibrium (CGE) model.

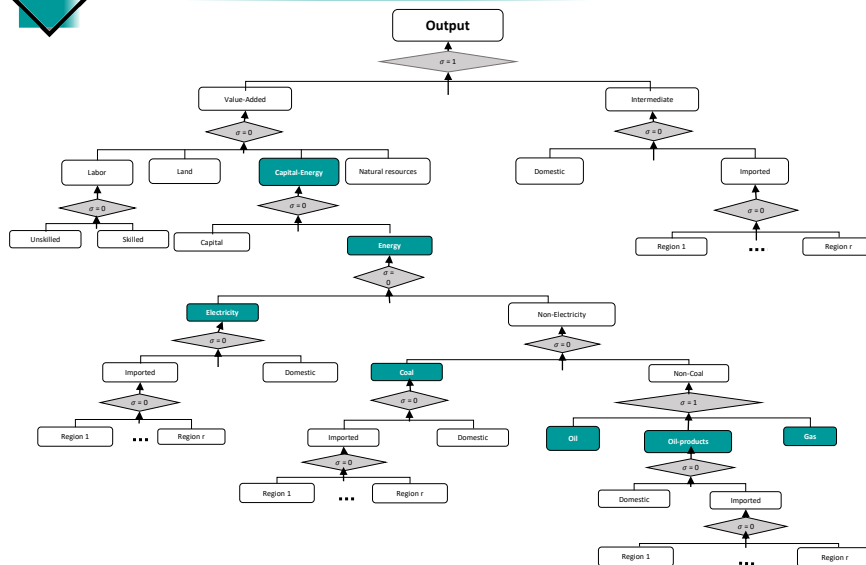
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## Method

- This study aims to empirically quantify the potential economic impacts of GHG emissions reduction and the opportunity cost the US is likely to pay using the GTAP-E multi-region, multi-sector static computable general equilibrium (CGE) model.
- The CGE model analyzes the economy as a whole and follows Leon Walras's general equilibrium theory which holds that all economies can attain equilibrium where demand and supply for all commodities equilibrate.
- CGE models constitute non-linear simultaneous equations formulated based on existing economic theories. The numerical models combine economic theory and actual economic data to computationally evaluate the impacts of policies or structural changes while still accounting for interdependence and feedback of sectors in the economy.
- *The numerical models describe the constrained optimizing behavior of economic agents such as the savers, investors, producers, exporters, importers, consumers, the government (Ko,1993).*

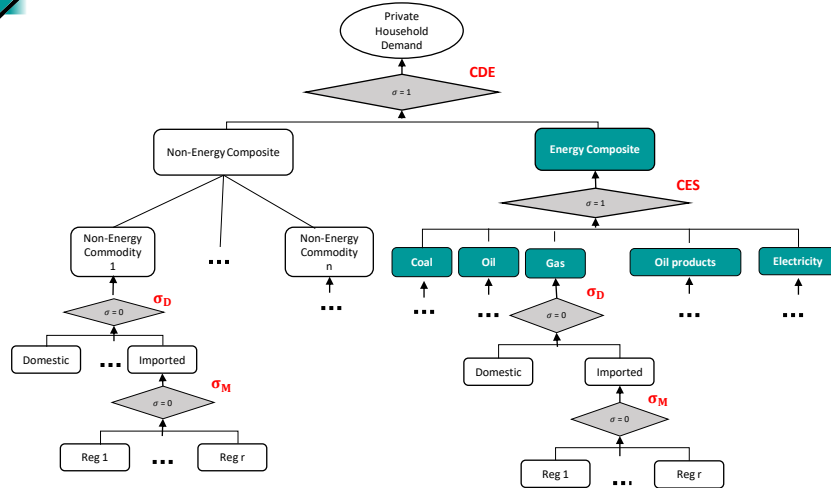
## Method - GTAP-E Production Structure



Source: Adapted from Burniaux, J., & Truong, T. (2002).



## Method - GTAP-Energy Private Household Consumption

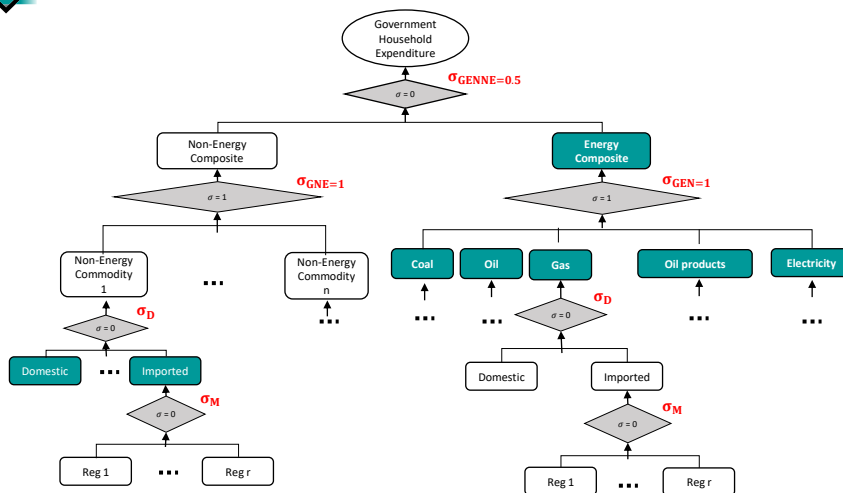


Source: Adapted from Burniaux, J., & Truong, T. (2002).

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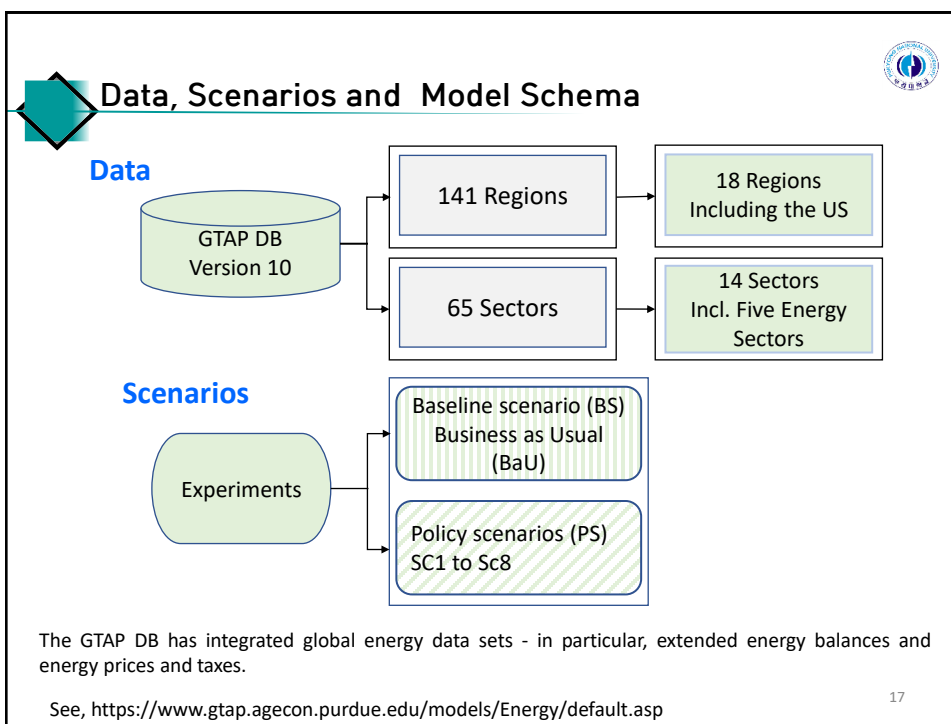


## Method - GTAP-Energy Government Expenditure



Source: Adapted from Burniaux, J., & Truong, T. (2002).

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## Table 2. Regional and Sectoral Aggregation (Coverage)

| No. | Region | Description                    | Sector      | Description                 |
|-----|--------|--------------------------------|-------------|-----------------------------|
| 1   | KOR    | Korea South                    | Agr         | Primary Agriculture         |
| 2   | JPN    | Japan                          | F_F         | Forest and fishing          |
| 3   | CHN    | China                          | Coal        | Coal mining                 |
| 4   | USA    | United States of America       | Oil         | Crude Oil                   |
| 5   | UK     | United Kingdom                 | Gas         | Natural gas extraction      |
| 6   | SAF    | South Africa                   | Oil_pcts    | Refined oil products        |
| 7   | KEN    | Kenya                          | PrcFood     | Processed food              |
| 8   | RWA    | Rwanda                         | En_Int_Ind  | Energy intensive industries |
| 9   | TZA    | Tanzania                       | TMV         | Transport Motor Vehicles    |
| 10  | UGA    | Uganda                         | Oth_Ind     | Other industries            |
| 11  | ETH    | Ethiopia                       | Electricity | Electricity                 |
| 12  | FSU    | Former Soviet Union            | Construct   | Construction only           |
| 13  | OIC    | Other industrialized countries | TransportS  | Transport Services          |
| 14  | OEX    | Oil exporters                  | OthSvcs     | Other Services              |
| 15  | EU27   | European Union 27              |             |                             |
| 16  | NAF    | Northern Africa                |             |                             |
| 17  | SSA    | Sub-Saharan Africa             |             |                             |
| 18  | ROW    | Rest of World                  |             |                             |

Source: GTAP Database version 10 (2019)



## Baseline scenario

Projections of economic growth, population, capital stock, skilled labor and unskilled labor for the period of 2014 to 2030.

- Real GDP: IIASA (Oliver et al. (2017))
- Population: World Population Prospects (UN, 2019))
- Skilled labor and Unskilled labor: IIASA (Keywan et al. (2017))
- Capital stock: CEPII projections (Foure et al. (2012))
- Arable land: Bruinsma (2011)

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## Policy scenarios

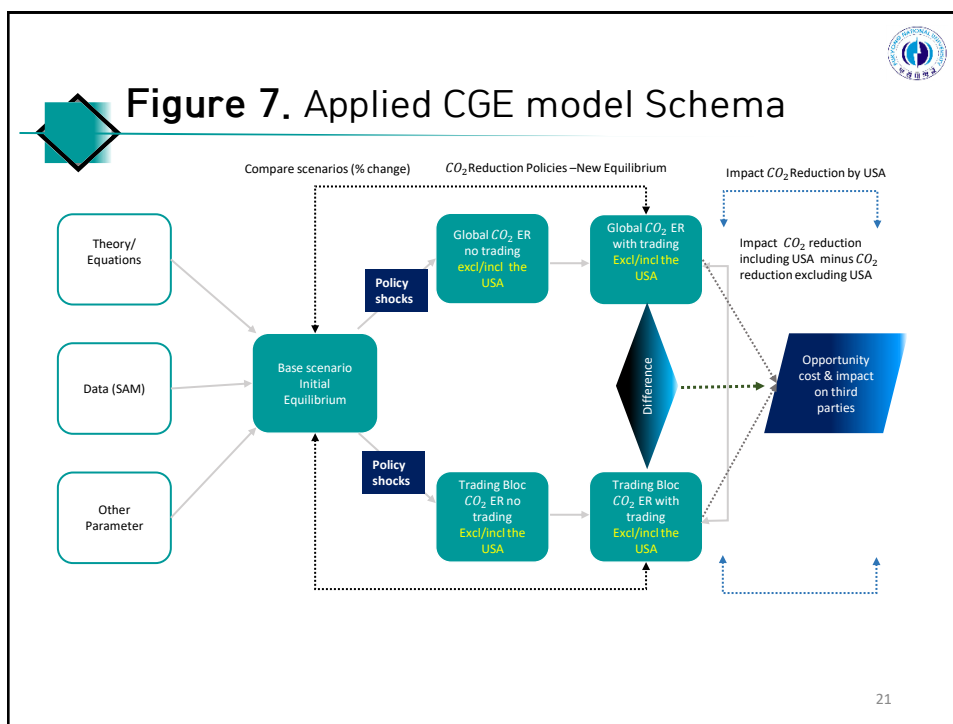
### World-wide emission reduction

- With emission trading 1). Sc1 – Excluding the US  
2). Sc2 – Including the US
- **With emission trading 3). Sc3 – Excluding the US  
4). Sc4 – Including the US**

### Major GHG emitters bloc

- With no emission trading 5). Sc5 – Excluding the US  
6). Sc6 – Including the US
- With emission trading 7). Sc7 – Excluding the US  
8). Sc8 – Including the US

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**Table 3. Policy Scenarios**

| Region/ Experiment / Scenario | CO2 Emission Reduction with no Use of Flexibility Mechanisms Excl / Incl USA |                                 |     | CO2 Emission Reduction with Trading Excl/Incl USA | CO2 Emission Reduction no Use of Flexibility Mechanisms by Major GHG Emitters Excl/ Incl USA |     | CO2 Emission Reduction by major GHG Emitters with Trading Excl/Incl USA |     |
|-------------------------------|------------------------------------------------------------------------------|---------------------------------|-----|---------------------------------------------------|----------------------------------------------------------------------------------------------|-----|-------------------------------------------------------------------------|-----|
|                               | Sc1                                                                          | Sc2                             | Sc3 | Sc4                                               | Sc5                                                                                          | Sc6 | Sc7                                                                     | Sc8 |
| Korea                         |                                                                              |                                 |     |                                                   | 40% compared with 2018                                                                       |     |                                                                         |     |
| Japan                         |                                                                              |                                 |     |                                                   | 46-50% compared with 2013                                                                    |     |                                                                         |     |
| China                         |                                                                              |                                 |     |                                                   | 65% compared with 2005                                                                       |     |                                                                         |     |
| United States of America      |                                                                              |                                 |     |                                                   | 50-52% compared with 2005                                                                    |     |                                                                         |     |
| United Kingdom                |                                                                              |                                 |     |                                                   | 68% compared with 1990                                                                       |     |                                                                         |     |
| South Africa                  |                                                                              | 37-43% compared with 201        |     |                                                   |                                                                                              |     |                                                                         |     |
| Kenya                         |                                                                              | 32% compared with 2030          |     |                                                   |                                                                                              |     |                                                                         |     |
| Rwanda                        |                                                                              | 16-38% compared with 2030       |     |                                                   |                                                                                              |     |                                                                         |     |
| Tanzania                      |                                                                              | 20.51-50.57% compared with 2030 |     |                                                   |                                                                                              |     |                                                                         |     |
| Uganda                        |                                                                              | 22% compared with 2030          |     |                                                   |                                                                                              |     |                                                                         |     |
| Ethiopia                      |                                                                              | 14-69% compared with 2030       |     |                                                   |                                                                                              |     |                                                                         |     |
| Former Soviet Union           |                                                                              |                                 |     |                                                   |                                                                                              |     |                                                                         |     |
| Other Industrial Countries    |                                                                              |                                 |     |                                                   |                                                                                              |     |                                                                         |     |
| Oil Exporting Countries       |                                                                              |                                 |     |                                                   |                                                                                              |     |                                                                         |     |
| European Union27              |                                                                              |                                 |     |                                                   | 55% compared with 1990                                                                       |     |                                                                         |     |
| North Africa                  |                                                                              |                                 |     |                                                   |                                                                                              |     |                                                                         |     |
| Sub-Saharan Africa            |                                                                              |                                 |     |                                                   |                                                                                              |     |                                                                         |     |
| Rest of World                 |                                                                              |                                 |     |                                                   |                                                                                              |     |                                                                         |     |

Source: Joergen Fenhann, UNEP Copenhagen Climate Centre (April 1, 2022), UNFCC  
Reference for Applied Experiments:  
1. Scenario 1 and 2 forms experiment 1 abbreviated as WNeMTRD  
2. Scenario 3 and 4 forms experiment 2 abbreviated as WeMTRD  
3. Scenario 5 and 6 forms MeMTRD experiment 3 abbreviated as MeMTRD  
4. Scenario 7 and 8 forms MeMTRD experiment 4 abbreviated as MeMTRD

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## Simulations Results

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**Table 4. Impact of CO<sub>2</sub> Reduction on Real GDP (% Change)**

| Region \ Experiment / Scenario | WNeMTRD         |                 | WeMTRD          |                 | MeMTRD          |                 | MeMTRD          |                 |
|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                | Sc1<br>excl USA | Sc2<br>incl USA | Sc3<br>excl USA | Sc4<br>incl USA | Sc5<br>excl USA | Sc6<br>incl USA | Sc7<br>excl USA | Sc8<br>incl USA |
| Korea                          | -2.685          | -2.693          | -0.124          | -0.218          | -0.224          | -0.461          | -0.224          | -0.461          |
| Japan                          | -1.860          | -1.852          | -0.055          | -0.101          | -0.173          | -0.336          | -0.173          | -0.336          |
| China                          | -0.418          | -0.414          | -0.438          | -0.685          | -0.524          | -0.965          | -0.524          | -0.965          |
| United States                  | 0.013           | -0.643          | -0.127          | -0.242          | -0.159          | -0.356          | -0.159          | -0.356          |
| United Kingdom                 | -4.002          | -4.010          | -0.062          | -0.107          | -0.127          | -0.245          | -0.127          | -0.245          |
| South Africa                   | -0.232          | -0.182          | -0.522          | -0.857          | 0.027           | 0.038           | 0.027           | 0.038           |
| Kenya                          | 2.241           | 1.836           | 0.400           | 0.592           | 0.000           | -0.009          | 0.000           | -0.009          |
| Rwanda                         | 0.144           | 0.116           | 0.054           | 0.073           | -0.006          | -0.012          | -0.006          | -0.012          |
| Tanzania                       | 0.304           | 0.230           | 0.092           | 0.135           | 0.009           | 0.012           | 0.009           | 0.012           |
| Uganda                         | 0.078           | 0.061           | 0.024           | 0.033           | 0.001           | 0.001           | 0.001           | 0.001           |
| Ethiopia                       | 0.772           | 0.835           | 0.406           | 0.648           | 0.007           | 0.007           | 0.007           | 0.007           |
| Former Soviet Union            | -0.494          | -0.450          | 0.591           | 0.556           | -0.034          | -0.104          | -0.034          | -0.104          |
| Other Industrial Countries     | -0.309          | 0.004           | -0.111          | -0.186          | 0.021           | 0.029           | 0.021           | 0.029           |
| Oil Exporting Country          | -0.163          | -0.184          | -0.206          | -0.338          | -0.033          | -0.061          | -0.033          | -0.061          |
| EU27                           | -2.188          | -2.182          | -0.086          | -0.142          | -0.185          | -0.342          | -0.185          | -0.342          |
| North Africa                   | 0.004           | 0.005           | -0.187          | -0.320          | 0.000           | -0.004          | 0.000           | -0.004          |
| Sub-Saharan Africa             | -0.111          | -0.015          | -0.007          | -0.020          | -0.015          | -0.032          | -0.015          | -0.032          |
| Rest of the World              | -0.004          | 0.020           | -0.103          | -0.179          | 0.031           | 0.054           | 0.031           | 0.054           |

Source: Authors' calculation

In terms of real GDP, USA's opportunity cost under world wide emission reduction with trading amounts to a 0.115% decline in real GDP.

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**Table 5. Impact of CO<sub>2</sub> Reduction on Welfare US\$ billion**

| Region \ Experiment / Scenario | NeMTRD          |                 | WeMTRD          |                 | MeMTRD          |                 | MeMTRD          |                 |
|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                | Sc1<br>excl USA | Sc2<br>incl USA | Sc3<br>excl USA | Sc4<br>incl USA | Sc5<br>excl USA | Sc6<br>incl USA | Sc7<br>excl USA | Sc8<br>incl USA |
| Korea                          | -19.63          | -18.82          | -2.36           | -3.02           | -19.04          | -19.49          | -5.42           | -8.02           |
| Japan                          | 6.99            | 9.28            | 0.35            | 5.15            | -5.83           | -3.61           | -5.52           | -8.61           |
| China                          | -218.58         | -208.32         | -201.53         | -248.96         | -196.06         | -205.18         | -233.78         | -308.83         |
| United States                  | -3.52           | -135.70         | 1.47            | -95.96          | -1.24           | -135.15         | 5.64            | -116.20         |
| United Kingdom                 | -49.87          | -50.45          | -8.87           | -13.06          | -8.49           | -52.16          | -11.63          | -20.63          |
| South Africa                   | -2.27           | -1.89           | -3.66           | -4.09           | 0.60            | 1.52            | 0.75            | 1.16            |
| Kenya                          | 26.34           | 23.78           | 5.31            | 7.67            | 0.05            | 0.86            | 0.12            | 0.12            |
| Rwanda                         | -0.01           | 0.07            | 0.07            | 0.10            | -0.02           | -0.10           | -0.03           | -0.04           |
| Tanzania                       | 7.14            | 7.00            | 3.16            | 4.66            | 0.05            | 0.20            | 0.07            | 0.12            |
| Uganda                         | 1.19            | 1.17            | 1.68            | 2.48            | -0.07           | -0.26           | -0.09           | -0.14           |
| Ethiopia                       | 11.59           | 12.49           | 7.02            | 10.16           | 0.02            | 0.19            | 0.04            | 0.09            |
| Former Soviet Union            | -47.48          | -52.53          | -12.29          | -21.35          | -10.83          | -50.77          | -10.73          | -19.77          |
| Other Industrial Countries     | -43.51          | -44.77          | -20.42          | -27.87          | -2.56           | -19.22          | 0.18            | -1.73           |
| Oil Exporting Country          | -82.62          | -102.94         | -72.42          | -99.95          | -22.22          | -80.12          | -26.00          | -43.94          |
| European Union27               | -15.20          | -7.72           | -9.87           | -12.83          | -1.95           | -22.22          | -26.14          | -40.53          |
| North Africa                   | -5.93           | -6.40           | -9.07           | -11.96          | -1.29           | -6.28           | -1.46           | -2.42           |
| Sub-Saharan Africa             | -2.76           | -3.69           | 3.20            | 5.24            | -3.37           | -11.93          | -4.21           | -7.24           |
| Rest of the World              | -34.37          | -20.49          | -30.27          | -28.19          | 14.55           | -19.22          | 19.02           | 38.49           |

Source: Authors calculation

USA's opportunity cost under world wide emission reduction with trading with respect to welfare amounts a loss of US\$ 97.43billion.

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**Table 6. Impact on Domestic Production by Sector  
% Change Sc3**

| Sector\ Region              | KOR  | JPN    | CHN    | USA    | UK     | SAF    | KEN    | RWA    | TZA    | UGA    | ETH    | FSU    | OIC    | OEX   | EU27   | NAF    | SSA    | ROW    |
|-----------------------------|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------|--------|--------|--------|
| Agriculture                 | -0.6 | -0.16  | 0.09   | -0.37  | 0.01   | -0.01  | -0.27  | 0.28   | 0.17   | -0.02  | 1.50   | 0.39   | -0.17  | 0.11  | -0.47  | 0.41   | 0.05   | -0.35  |
| Forest and Fishery          | -0.8 | -0.19  | -0.19  | -0.49  | -0.27  | -0.37  | 0.27   | 0.17   | -0.13  | 0.39   | 3.38   | -0.26  | -0.28  | -0.27 | -0.44  | -0.09  | 0.01   | -0.18  |
| Coal                        | 39.6 | -51.51 | -37.09 | -21.44 | -15.42 | -15.91 | -34.86 | -24.14 | -29.98 | -26.49 | -0.12  | -11.12 | 1.80   | -2.68 | -24.85 | -43.02 | -10.71 | -15.23 |
| Oil                         | -2.6 | -2.70  | -3.31  | -4.58  | -3.95  | -3.36  | -8.09  | -1.94  | -0.52  | -4.54  | -4.47  | -2.15  | -3.96  | -1.66 | -3.70  | -2.93  | -3.45  | -4.04  |
| Gas                         | 0.3  | -0.41  | -22.32 | -36.88 | -30.38 | -6.32  | -10.43 | -5.03  | -0.01  | -6.93  | -0.12  | -14.87 | -13.45 | -2.53 | -11.32 | -6.21  | -6.82  | -18.68 |
| Oil Products                | 0.6  | 1.49   | -5.25  | -3.56  | 0.15   | -8.64  | -2.66  | -17.02 | -17.54 | -21.71 | -42.71 | -1.19  | -4.00  | -6.63 | 0.10   | -6.21  | 0.64   | -1.72  |
| Processed Food              | -0.5 | -0.14  | -0.27  | -0.10  | -0.10  | 0.96   | -1.08  | 0.83   | -0.92  | -0.99  | 2.00   | 0.65   | 0.03   | 0.70  | -0.45  | 0.27   | -0.07  | -0.37  |
| Energy Intensive Industries | 2.1  | 0.86   | -1.79  | 0.76   | 2.50   | -2.61  | -16.07 | -0.61  | -9.55  | -6.74  | -12.78 | -0.88  | 3.05   | 4.50  | 1.42   | 0.66   | 1.43   | -1.85  |
| Transport Motor Vehicle     | -1.4 | -1.27  | -0.18  | -0.22  | 0.13   | 2.33   | -14.20 | -2.21  | -8.06  | -8.80  | -11.73 | 0.59   | 1.21   | 2.60  | -0.42  | 0.90   | -1.37  | -0.39  |
| Other Industries            | -1.4 | -1.31  | 0.53   | -0.27  | 0.56   | 0.83   | -16.13 | -5.11  | -12.56 | -9.88  | -15.42 | 1.44   | 1.19   | 3.01  | -0.49  | 1.89   | -1.31  | -1.96  |
| Electricity                 | -7.8 | -4.40  | -14.66 | -7.88  | -3.56  | -31.96 | 0.65   | -2.55  | 0.46   | -2.15  | 1.15   | -7.68  | -3.39  | -6.43 | -2.95  | -5.77  | 4.72   | -5.67  |
| Construct                   | -0.1 | -0.54  | -0.93  | -0.23  | -0.11  | -0.75  | 1.86   | 0.44   | 2.60   | 2.28   | 4.80   | 0.08   | -0.19  | -0.84 | -0.10  | -0.30  | 0.31   | 2.81   |
| TransportS                  | -0.3 | 0.33   | -0.80  | -1.45  | 0.57   | -4.71  | -1.56  | -1.86  | -9.70  | -5.03  | -12.10 | -0.69  | -0.31  | -4.69 | 0.37   | -3.74  | -1.29  | -1.10  |
| OthSvcs                     | -0.3 | -0.13  | -0.43  | 0.11   | -0.12  | -0.10  | 1.44   | -0.02  | 1.46   | 0.68   | -1.03  | 0.18   | -0.09  | -0.41 | -0.14  | -0.23  | 0.17   | 0.00   |

Source: Authors' calculations

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**Table 7. Impact of CO<sub>2</sub> Reduction Wit Trading on Domestic Production by Sector % Change (Sc4)**

| Sector\Region               | KOR    | JPN    | CHN    | USA    | UK     | SAF    | KEN    | RWA    | TZA    | UGA    | ETH    | FSU    | OIC    | OEX   | EU27   | NAF    | SSA    | ROW    |
|-----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------|--------|--------|--------|
| Agriculture                 | -1.00  | -0.26  | 0.05   | -0.10  | 0.04   | -0.21  | -0.43  | 0.41   | 0.23   | -0.05  | 2.12   | 0.54   | -0.24  | 0.15  | -0.69  | 0.52   | 0.07   | -0.56  |
| Forest and Fishery          | -1.19  | -0.26  | -0.29  | 0.03   | -0.37  | -0.55  | 0.38   | 0.26   | -0.16  | 0.57   | 4.81   | -0.39  | -0.38  | -0.38 | -0.58  | -0.12  | 0.03   | -0.26  |
| Coal                        | -45.92 | -59.83 | -45.40 | -27.15 | -20.75 | -21.16 | -45.03 | -30.97 | -38.64 | -34.20 | -0.25  | -15.50 | 0.12   | -4.17 | -31.41 | -51.68 | -14.88 | -19.72 |
| Oil                         | -3.92  | -4.11  | -5.14  | -6.19  | -5.90  | -5.36  | -12.53 | -2.93  | -0.58  | -6.94  | -7.14  | -3.26  | -5.93  | -2.59 | -5.56  | -4.50  | -5.20  | -6.19  |
| Gas                         | 0.34   | -0.64  | -38.32 | -46.49 | -43.54 | -8.79  | -16.34 | -8.37  | -0.01  | -11.24 | -0.16  | -19.13 | -18.08 | -3.01 | -15.45 | -8.12  | -9.54  | -24.52 |
| Oil Products                | 0.71   | 2.01   | -7.64  | -5.39  | 0.10   | -12.35 | -3.66  | -23.18 | -23.85 | -29.22 | -53.45 | -1.97  | -5.89  | -9.60 | -0.02  | -9.16  | 0.66   | -2.69  |
| Processed Food              | -0.77  | -0.12  | -0.38  | -0.15  | -0.14  | 1.23   | -1.61  | 1.26   | -1.37  | -1.46  | 2.72   | 0.88   | -0.05  | 1.00  | -0.69  | 0.36   | -0.08  | -0.62  |
| Energy Intensive Industries | 2.93   | 0.88   | -2.67  | 2.55   | 3.65   | -4.10  | -22.28 | -1.09  | -14.04 | -9.89  | -18.71 | -1.49  | 4.45   | 6.37  | 2.00   | 0.75   | 1.96   | -2.91  |
| Transport Motor Vehicle     | -2.35  | -2.53  | -0.43  | 1.13   | 0.15   | 2.52   | -19.69 | -3.22  | -11.75 | -12.70 | -17.23 | 0.71   | 1.27   | 3.67  | -0.77  | 1.11   | -1.84  | -1.09  |
| Other Industries            | -1.77  | -1.97  | 0.30   | 1.68   | 1.11   | 0.81   | -22.43 | -7.29  | -17.94 | -13.98 | -21.58 | 2.19   | 2.06   | 4.48  | -0.46  | 2.60   | -1.72  | -3.12  |
| Electricity                 | -10.89 | -6.28  | -19.15 | -10.80 | -5.00  | -40.14 | 1.03   | -3.64  | 0.65   | -3.03  | 0.81   | -10.91 | -4.70  | -8.61 | -4.13  | -7.58  | 6.44   | -7.88  |
| Construct                   | -0.21  | -1.03  | -1.19  | -0.66  | -0.16  | -0.85  | 2.68   | 0.67   | 3.83   | 3.34   | 6.81   | 0.02   | -0.27  | -1.18 | -0.13  | -0.37  | 0.47   | 4.38   |
| TransportS                  | -0.73  | 0.34   | -1.21  | -1.82  | 0.73   | -6.69  | -2.18  | -2.72  | -13.78 | -7.19  | -17.59 | -1.15  | -0.57  | -6.70 | 0.38   | -5.48  | -1.90  | -1.66  |
| OthSvcs                     | -0.38  | -0.10  | -0.55  | -0.12  | -0.20  | -0.08  | 2.05   | -0.03  | 2.12   | 1.00   | -1.40  | 0.18   | -0.13  | -0.58 | -0.23  | -0.30  | 0.25   | 0.01   |

Source: Authors' calculations

Emission trading is shown to reduce the negative impact of CO<sub>2</sub> reduction on domestic production of Forest and fishery, Transport Motor Vehicle, and Other Industries for USA. Domestic production in all the energy sectors declines significantly

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## Concluding Remarks

- The GDP losses are mainly due to a significant reduction in domestic production in coal, oil, oil products, transport, and construction sectors for most of the regions.
- USA's opportunity cost under world wide emission reduction with trading amounts to a 0.115% decline in real GDP.
- *The spillover effects of CO<sub>2</sub> emission reduction by the USA on real GDP are heterogenous*. With developed regions like Korea, Japan, China, UK South Africa, EU27, Oil exporting countries and other industrialized countries facing a decline in real GDP, while developing regions like Ethiopia, Kenya, Rwanda and Uganda experiencing a rise in real GDP.

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## Concluding Remarks

- *Welfare loss for developed regions emanates from CO<sub>2</sub> trade imbalance, structural inefficiencies, and investments. On the other hand, welfare loss for the developing regions is due to the unfavorable terms of trade and loss of investments.*
- With emission trading, the negative effect on domestic production is significantly reduced (considering the reference scenarios Sc1, SC2 for the world-wide  $[[CO]]_2$  emission reduction experiment).
- Emission trading has a positive effect on the manufacturing sectors of the developed countries, but the manufacturing sectors for developing countries are severely and negatively affected.
- The USA's faces significant opportunity costs of CO<sub>2</sub> emission reduction in energy sectors, and the transport services sector which amount to a decline in manufacturing of

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## Future Research Work

- Examining use of carbon tax as an alternative in mitigating CO<sub>2</sub> emission by the USA and major trading partners.
- Incorporating the time component to account for the dynamic nature of the impact of CO<sub>2</sub> emission on climate change.
- Estimating the social cost of CO<sub>2</sub> emission.

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