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Development of CO_2 Emissions and Impact of Carbon Pricing

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Abstract

Global greenhouse gas (GHG) emissions have continued to increase. The targets of GHG emissions reduction under the Paris Agreement have been far from achievement. Carbon pricing has been implemented but it is limited, covering less than a quarter of global GHG emissions. This paper presents an overview of recent developments in carbon dioxide (CO_2) emissions and investigates quantitatively the relative significance of the impact of carbon pricing, using a Computable General Equilibrium (CGE) model. The results of model simulations suggest that the impact of carbon pricing in the European Union (EU) member states and the Organisation for Economic Co-operation and Development (OECD) countries would be limited compared with that of a global initiative. Carbon tax (once introduced in a strong enough form worldwide, in particular if it included developing countries) would be effective for substantially reducing global CO_2 emissions. However, the adverse economic impact of carbon pricing would be serious and much larger than the magnitude of possible carbon tax revenue. On the other hand, the impact of a carbon border adjustment mechanism (CBAM) would be minor compared with that of a carbon tax, regardless of the coverage of countries. Trade effects of a CBAM could more or less be offset by trade liberalization. The economic and trade impact of carbon pricing would vary by region as well as by sector. Climate and trade policies would need to be well designed and based on sound quantitative analysis.

Key words: carbon tax, carbon border adjustment mechanism (CBAM), European Union (EU), Computable General Equilibrium (CGE) model
JEL classification: C68, F13, Q58

Development of CO_2 Emissions and Impact of Carbon Pricing

I. Introduction

Global greenhouse gas (GHG) emissions have continued to increase. There has been concern that global warming would exceed the goal of temperature increase limits set out under the Paris Agreement. Carbon pricing initiatives have been implemented, but their coverage of GHG emissions is not yet extensive enough. In the meantime, the European Union (EU) has agreed to introduce a carbon border adjustment mechanism (CBAM) in 2023. The impact of the EU CBAM has been a growing concern, not just for the EU but also for trade partners outside the EU, including both developed and developing countries.

This study has two objectives, first to overview the recent developments in carbon dioxide (CO_2) emissions, as mentioned above, to provide background information for the analysis of the subjects in this paper. Trends over time and the current state of CO_2 emissions continue to vary among countries. One key difference has been observed between developed and developing countries: developed countries have already generated major CO_2 emissions during the development of their economies, and have now begun to reduce emissions. On the other hand, developing countries still need to grow, and will inevitably emit CO_2 to some extent in a foreseeable future. Those differences across regions would have to be reflected in the variety of CO_2 emission reduction targets and policies among regions. Another difference that might be addressed is that between fossil fuel exporters and importers.

Second, the study aims to investigate the relative significance of the impact of carbon pricing in a quantitative manner using a global Computable General Equilibrium (CGE) model of economy, trade, and environment. The investigation will focus more on the impact of carbon pricing on trade and economy than on CO_2 emissions (and not necessarily temperature). The estimated impact of carbon pricing will likely vary depending on the structure of the CGE model used. The broader intent of this study is to compare the estimated impact among alternative policy scenarios rather than to present the absolute magnitude of individual impact. Those comparisons will be made from the perspective of the varying scope of the regions taking initiatives, as well as the variety of policies. Alternative policies to be examined will be extended to cover trade liberalization beyond carbon pricing.

The remaining part of this paper is organized as follows. Chapter II will describe the development of CO_2 emissions; discussion of trends in CO_2 emissions over time will be followed by discussion of the current state of implementation of the Paris Agreement and carbon pricing. Chapter III will analyze the impact of carbon pricing; review selected recent literature; and present a framework of model simulations including data and model, along with scenarios and assumptions. The results of the estimation of the impact of carbon pricing on CO_2 emissions, economy, and trade (and of the impact of trade liberalization) will be presented. Chapter IV will provide brief conclusions.

II. Development of CO_2 emissions

1) Trends in CO_2 emissions

Global GHG emissions have continued to increase. According to IPCC (2022), those amounted to around 59 giga tonnes (Gt) CO_2 equivalent in 2019 in terms of net anthropogenic emissions. That was before the short hiatus resulting from the temporary disarray of economic activities resulting from the 2019 coronavirus disease (COVID-19) pandemic. IPCC (2022) argues that by 2019, the increase in CO_2 from fossil fuel and industry constituted the largest global GHG emissions increase since 1990. Those emissions have accounted for some two thirds of total emissions, followed by methane and then net CO_2 from land use, land-use change, and forestry, as is shown in Table 1.

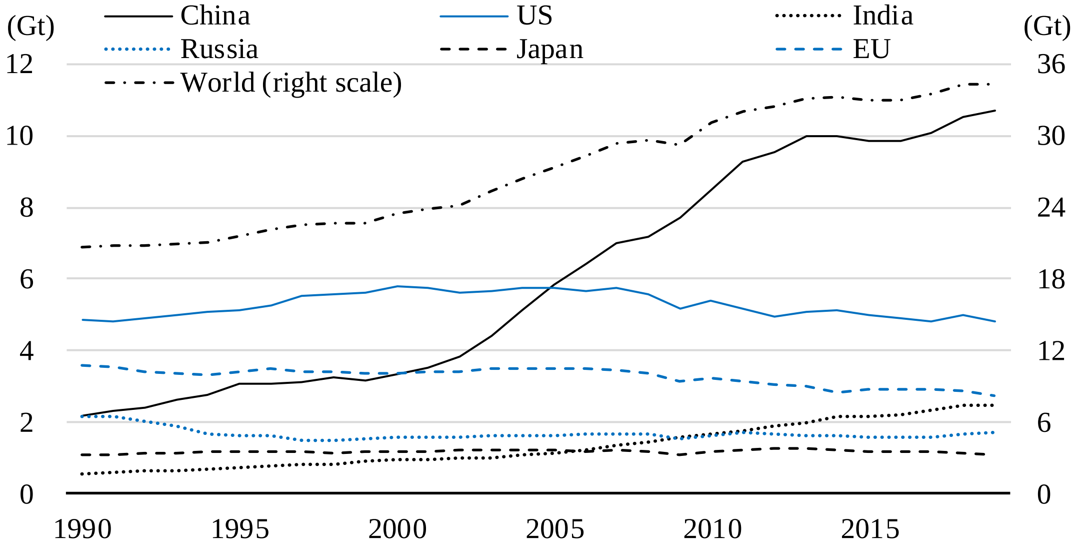
Those persistent increases in global CO_2 emissions, which may have been largely the result of increases in developing countries, including China and India, more than offset decreases in developed countries including the United States (US), Japan and the EU, are shown in Chart 1-A. The increase of CO_2 emissions in China contributed to a global increase of around 62% between 1990 and 2019; that in India contributed around 14%. China has been ranked first in terms of absolute levels of CO_2 emissions in the world, with a share of around 31% in 2019, followed by the US (14%), India (7%), Russia (5%), and Japan (3%). It may be noted that those five countries in total accounted for

Table 1 Composition of GHG emissions (2019)

	Emissions (Gt)	Ratio (%)
CO_2 from fossil flue and industry	38 ± 3	64%
Net CO_2 from land use, land-use change, forestry	6.6 ± 4.6	11%
Methane (CH_4)	11 ± 3.2	18%
Nitrous oxide (N_2O)	2.7 ± 1.6	4%
Fluorinated gas (HFCs, PFCs, SF_6, NF_3)	1.4 ± 0.41	2%
Total	59 ± 6.6	100%

Source: Based on IPCC (2022).

Chart 1-A Trends in CO_2 emissions

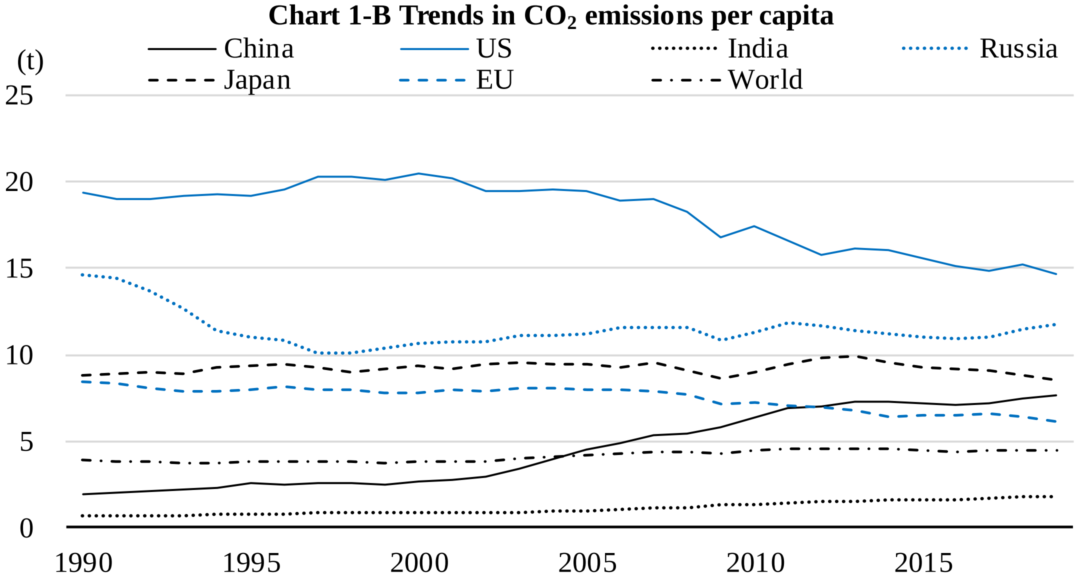


Source: Based on GHG Emissions, Climate Watch, World Resources Institute.

around 60%. Meanwhile, the 27 EU member states in total shared around 8%.

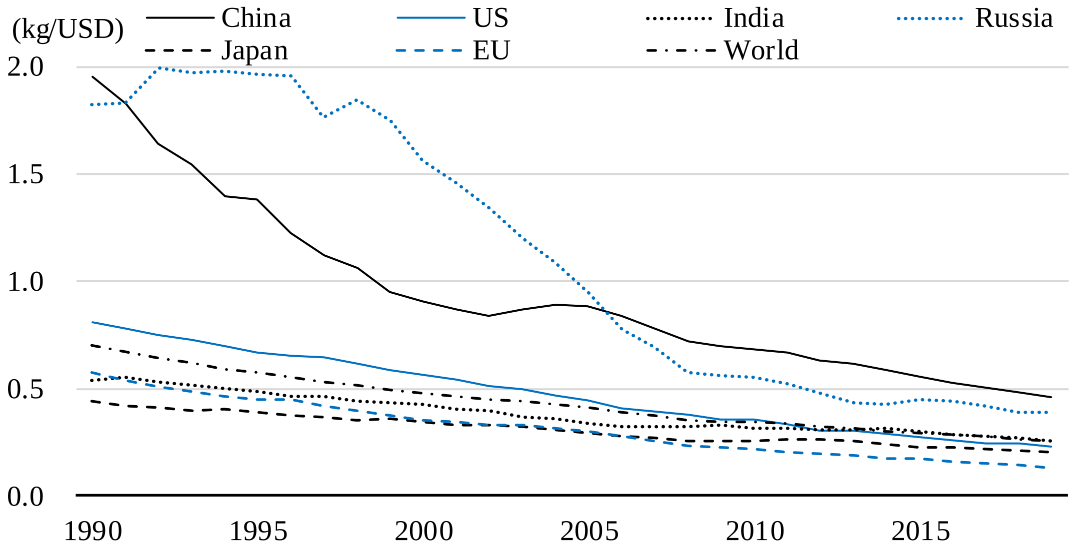
It would not be fair to compare CO_2 emissions performance among countries by absolute emissions levels, given the variation in economic size and development stage. In terms of per capita CO_2 emissions, shown in Chart 1-B, the relative emissions levels in the US have been falling—although they remain the highest among major countries, followed by those in Russia and Japan. On the other hand, CO_2 emissions per capita in China were lower than the global average until the mid-2000s and lower than those in the EU until the early 2010s. Meanwhile, per capita emissions in India have been rising but

Chart 1-B Trends in CO_2 emissions per capita



Source: Based on GHG Emissions, Climate Watch, World Resources Institute.

Chart 1-C Trends in CO_2 emissions per GDP



Source: Based on GHG Emissions, Climate Watch, World Resources Institute.

remain less than half the global average.

On the other hand, CO_2 emissions per Gross Domestic Product (GDP) in terms of purchasing power parity (PPP) US dollars (USD) have been falling in all major countries shown in Chart 1-C, notably in China and Russia, and fallen within a narrower range than that of per capita emissions reported above. In 2019, China's per GDP emissions were the highest among major regions, and slightly less than double the global average, whereas the lowest in the EU were around half the global average. On the other hand, per capita emissions in the US were more than three times the global average and around eight times those in the lowest ranked country, India.

The comparison of the above three CO_2 emission indicators for major countries is summarized once again in Table 2. The primary global concerns would be to reduce

Table 2 Comparison of CO_2 emission indicators

	Emissions (Gt)		Emissions per capita (t)		Emissions per GDP (kg/USD)	
	1990	2019	1990	2019	1990	2019
China	2.17	10.71	1.91	7.61	1.95	0.46
US	4.84	4.82	19.41	14.67	0.81	0.23
India	0.56	2.46	0.65	1.78	0.54	0.26
Russia	2.16	1.70	14.62	11.80	1.82	0.39
Japan	1.09	1.08	8.83	8.54	0.44	0.20
EU	3.56	2.72	8.48	6.09	0.57	0.13
World	20.63	34.34	3.90	4.44	0.70	0.25

Source: Based on GHG Emissions, Climate Watch, World Resources Institute.

absolute levels of CO_2 emissions, but those levels have continued to rise substantially in China and India although per GDP emissions have been falling. Another version of this narrative has it that per capita emissions have also been rising in China and India but are still lower than those in the US, Russia, and Japan. Further consideration of the appropriate indicator for assessment of the state of CO_2 emissions would be worthwhile.

2) Implementation of Paris Agreement

The Paris Agreement was adopted in December 2015 by close to 200 parties at the 21st Conference of Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) in Paris; it went into force in November 2016. According to UN (2015),

> “This Agreement … aims to strengthen the global response to the threat of climate change … including by: (a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels …;” (Article 2 1.)
>
> “Each Party shall communicate a nationally determined contribution every five years ….” (Article 4 9.)

Nationally Determined Contributions (NDCs) toward the reduction of GHG emissions have varied among parties, as is shown in Table 3, based on NDC Registry, United Nations (UN) Climate Change.[1] The target rates for reduction of GHG emissions have been ranging between 46% in Japan and 70% in Russia among major parties. The base year, on the basis of which the emission reduction rates have been calculated, has been around the peak year of CO_2 emissions since 1990 in the US, Russia, Japan, and the EU within the period 1990 to 2013[2]. Meanwhile, the base year has been 2005 in China and India, where emissions continue to increase. Moreover, the measurement of emissions

Table 3 Nationally determined contributions (NDCs)

Party	Submission	Measurement	Base	Target	Rate
China	2021 Oct	CO_2 emissions per unit of GDP	2005	2030	over 65%
US	2021 Apr	Net GHG emissions	2005	2030	50-52%
India	2022 Aug	Emissions intensity of its GDP	2005	2030	45%
Russia	2020 Nov	GHG emissions	1990	2030	70%
Japan	2021 Oct	GHG emissions	FY2013	FY2030	46%
EU	2020 Dec	Net domestic GHG emissions	1990	2030	At least 55%

Source: Author's compilation based on NDC Registry United Nations Climate Change.

[1] https://unfccc.int/NDCREG, accessed 29 January 2023.

[2] A base year and a target year are specified in terms of fiscal year (FY) in Japan.

Table 4 Progress in reducing CO_2 emissions

	Emissions			Emissions per GDP			Target
	Base (Gt)	2019 (Gt)	Change (%)	Base (kg/USD)	2019 (kg/USD)	Change (%)	(%)
China	5.82	10.71	83.8	0.88	0.46	-48.3	65.0
US	5.75	4.82	-16.3	0.44	0.23	-48.9	50.0-52.0
India	1.14	2.46	116.1	0.34	0.26	-23.1	45.0
Russia	2.16	1.70	-21.3	1.82	0.39	-78.8	70.0
Japan	1.26	1.08	-14.4	0.25	0.20	-19.7	46.0
EU	3.56	2.72	-23.5	0.57	0.13	-76.9	55.0

Source: Author's compilation based on GHG Emissions, Climate Watch, World Resources Institute; and NDC Registry, United Nations Climate Change.

has not been consistent across parties: the target in China and India has been set out in terms of emissions per GDP rather than the absolute levels of emissions adopted by various parties.

The progress of CO_2 emissions reduction with respect to the above targets under the Paris Agreement is compared across major parties in Table 4. CO_2 emissions have been reduced in the US, Russia, Japan, and the EU but those reductions have fallen far short of the targets. If the CO_2 emissions reduction rates from the base years to 2019 were simply extended to the target year 2030, emissions would be reduced by around 27% in the US, which is around half of the 50-52% target. The comparisons for other parties are also pessimistic; the extrapolated rate for Russia would be around 28%, less than half of the 70% target. Meanwhile, the rate is somewhat lower in Japan, around 36%, compared with the target of 46%, and in the EU around 31% compared with the target of 55%.

On the other hand, CO_2 emissions per GDP have been reduced in line with the targets but the absolute levels of CO_2 emissions have roughly doubled in China and India. It would not be appropriate to judge the achievement of emissions reductions in those countries by the current targets in per GDP figures as that evidence. One unresolved issue in key climate policy agenda would be the identification of an appropriate measure of GHG emissions reductions targets.

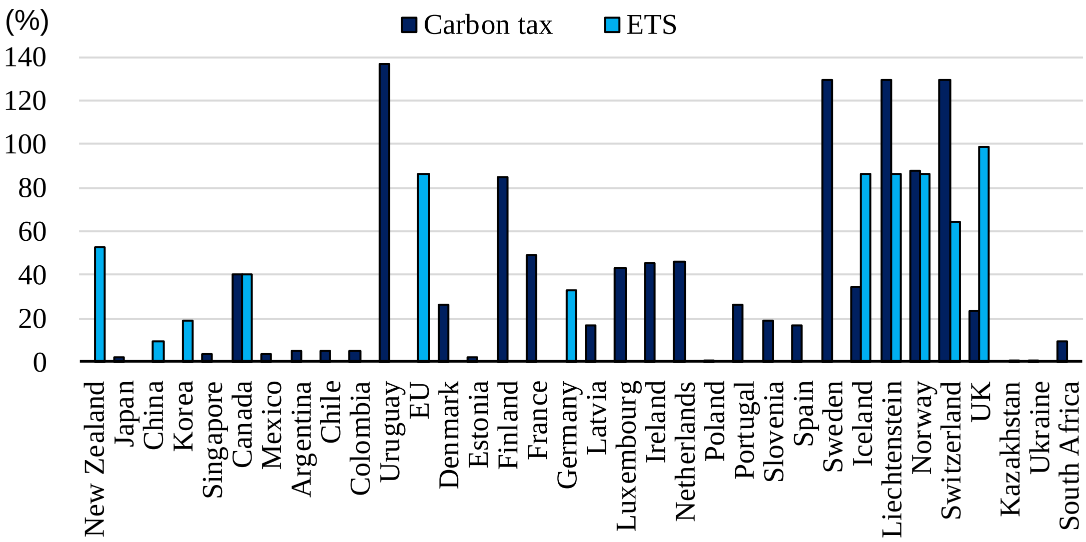
3) State of carbon pricing

Carbon pricing is a climate policy measure for the reduction of the quantities of CO_2 emissions by raising emissions prices. A few carbon pricing instruments have been implemented. Carbon tax imposes a fee like a tax on CO_2 emissions, generating price costs with the expectation of reducing emissions through economic activities. Emissions prices are fixed by governments and the quantities of emissions would be determined indirectly in the economy. On the other hand, an emissions trading system (ETS) sets an upper limit on levels of CO_2 emissions, and additional and/or surplus allowances and/or credits are traded under a "cap-and-trade" system and/or a "baseline-and-credit" system. The quantities of emissions limits are set directly by governments, and the prices of emissions are determined in the market based on the balance of supply and demand of emission allowances and/or credits. Meanwhile, credits generated by voluntary CO_2 emissions reduction activities could be traded under a carbon crediting mechanism. The prices of emissions are not necessarily be paid to governments; while, the quantities of emissions are dependent on economic activities.

Adoption of carbon pricing has been ongoing. As of April 2022, 68 carbon pricing instruments including carbon tax and ETS have been operating at national and subnational levels, according to World Bank (WB) annual report (WB, 2022). That said, instruments would only cover around 23%, or less than a quarter, of global GHG emissions.

Moreover, carbon prices are not yet high enough in many regions. The report of the High-Level Commission on Carbon Prices (WB, 2017) has concluded that carbon prices would need to be at least in the range of 40 to 80 USD per t CO_2 by 2020, and 50 to 100 USD per t CO_2 by 2030 to achieve the temperature target of the Paris Agreement.[3] However, as is shown in Chart 2, only six countries have carbon tax rates above 80 USD

Chart 2 Carbon price rates



Source: Based on Carbon Pricing Dashboard, World Bank.

[3] Parry, Black and Roaf (2021) propose a global carbon tax of around 75 USD per t CO2 by 2030 to reduce CO_2 emissions in line with pathways meeting the Paris temperature target.

per t CO_2: Uruguay, the highest, at around 137 USD per t CO_2, implemented in 2022; Switzerland (around 130 USD); and four member states of the European Economic Area (EEA), Liechtenstein (around 130 USD), Sweden (around 130 USD), Norway (around 88 USD) and Finland (around 85 USD).

In the meantime, in July 2021 the European Commission (EC) proposed the establishment of a CBAM. The EU Council and European Parliament reached provisional agreement in December 2022 to introduce a CBAM, which would go into effect gradually starting in 2023. The outline of the EU CBAM could be summarized as follows based on EC (2021a).

Why: Prevent the risk of carbon leakage and support climate mitigation.
What: EU importers buy carbon certificates corresponding to carbon price.
How: The price depends on the average auction price of EU ETS allowances.
Which goods: Initially cement, iron and steel, aluminum, fertilizers, electricity.
From whom: Except EEA members and Switzerland.
When: Transition starting in 2023, in operation from 2026.

The EC has primarily framed CBAM response to carbon leakage from the perspective of climate policy. It is possible that the EU would import more carbon intensive and therefore less carbon efficient goods and services from regions where CO_2 emissions standards are lower than those of the EU. The aim of a CBAM is equalizing the carbon prices of production of goods inside the EU and those imported from outside the EU. From the perspective of trade policy, the price competitiveness of products at home and abroad could be a matter of concern. However, the EU CBAM would be applied to imports by the EU, but the reimbursement of carbon prices for EU exports would not be included. Comparability with the World Trade Organization (WTO) has been considered to some extent.

II. Impact of carbon pricing

1) Selected recent literature

When the EC proposed a CBAM, it conducted an impact assessment to accompany the proposal. The economic impact of that CBAM and other EU climate initiatives was studied using a CGE model. According to a Commission Staff Working Document (EC, 2021b), GDP is estimated to decrease by 0.222% to 0.224% in 2023 under the two “MIX” scenarios without a CBAM, to meet the EU’s target of reducing emissions by at least 55%. On the other hand, under the six option CBAM scenarios presented there, GDP is estimated to decrease by 0.223% to 0.227%. The additional impact of a CBAM is indicated to be in a narrow range and moreover, to be minor compared with those of the EU's carbon price initiatives without a CBAM.

A number of studies have examined the impact of carbon pricing by means of CGE model simulations. The estimations of the impact of carbon pricing in selected recent studies, including EC (2021b) above, are summarized in Table 5. Recent studies have highlighted the impact of the EU CBAM not just on the EU, but also on the EU's trade partners. That said, the impact of a CBAM has generally been found to be much smaller than that of carbon tax without a CBAM. Devarajan, Go, Robinson and Thierfelder (2022) suggest that the impact of a CBAM in high-income regions would be around 0.1% to 0.2% in major countries, assuming a carbon tax of 75 USD per t CO_2 and associated levels of CBAM tariffs. UNCTAD (2021) has also estimated that real absorption in the EU would increase by around 4.6 billion USD under the EU CBAM, but would decrease by around 52.8 billion USD under the EU carbon price, assuming a carbon tax rate of 44 USD per t CO_2 and associated CBAM. A study comparing the impact of a CBAM with that of other carbon pricing initiatives would be of value to related work.

One key concern from the perspective of balanced economic growth in the world would be possible differences between developed and developing countries regarding the impact of carbon pricing, with particular interest in least developed countries (LDCs). UNCTAD (2021) has confirmed that exports in developed countries impact the

Table 5 Summary of recent estimates

EC (2021b)						
GDP in 2030 (%)	EU					
MIX scenarios	-0.222～-0.224					
with CBAM options	-0.223～-0.227					
Devarajan, Go, Robinson and Thierfelder (2022)						
Real absorption (%)	EU		US	China	India	Russia
All countries carbon tax	0.0		-0.3	-1.0	-0.4	-2.3
High-income regions carbon tax	0.1		-0.2	-0.1	0.1	-1.5
with CBAM (direct and indirect CO_2)	0.2		-0.2	-0.2	0.1	-1.7
UNCTAD (2021)						
Real income (million USD)	EU		Developed		Developing	
EU carbon price	-52,847		-51,370		1,175	
EU CBAM	4,591		2,485		-5,867	
He, Zhai and Ma (2022)						
GDP in 2030 (%)		Japan	US	China	India	Russia
EU CBAM to current scope		-0.002	-0.002	-0.007	-0.043	-0.193
EU CBAM to all goods and services		-0.016	-0.042	-0.170	-0.272	-0.636

Source: Author's compilation based on the literatures discussed.

replacement of exports in developing countries, which tend to be more carbon intensive. It is estimated that real absorption in developing countries would increase by around 1.2 billion USD under the EU's carbon prices without a CBAM, but would in turn decrease by around 5.9 billion USD under a CBAM on top of carbon prices. He, Zhai and Ma (2022) suggest that a CBAM would give rise to expansion of the macroeconomic gap between developed and developing countries. GDP is estimated to decrease in 2030 by 0.170% to 0.636% in China, India, and Russia (compared with 0.016% in Japan and 0.042% in the US) if the EU CBAM were extended to apply to all goods and services[4] under the assumption of a 75 USD per t CO_2 carbon tax incorporated in a CBAM. Given the overall situation, it would be interesting to study the impact of carbon pricing both within and outside the regions taking initiatives.

The above studies have also considered policy options for mitigating possible adverse impact on LDCs. UNCTAD (2022) has included "the use of revenue generated by the CBAM" by the EU in such policy options. He et al. (2022) discuss "the possibility of launching an Equitable Decarbonization Fund," recommending that the key role be played by the International Monetary Fund (IMF).

Meanwhile, Devarajan et al. (2022) further studied the impact of another climate and trade policy initiative, "climate club."[5] A key difference between a climate club and a CBAM is that in a climate club uniform tariffs are applied on imports from non-members regardless of the carbon content of products. Tariff penalties under a climate club are found to be effective for prompting non-members to join the club. It would be noted that the above effectiveness would be partly dependent on the assumed magnitudes of uniform tariff rates. That said, it would be valuable to extend the scope of studies in trade policy beyond CBAM related studies.

2) <u>Framework of model simulations</u>

a) Data and model

In this paper, the impact of carbon pricing is estimated using the Global Trade Analysis Project (GTAP) Data Base 10 (Aguiar, Chepeliev, Corong, McDougall and van der Mensbrugghe, 2019) and the GTAP-E model (Burniaux and Truong, 2002) revised in McDougall and Golub (2007), and solved using GEMPACK software (Horridge, Jerie, Mustakinov and Schiffmann, 2018).

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[4] This option was considered not viable and was discarded in EC (2021b).
[5] The notion of climate club is described in Nordhaus (2015).

The GTAP Data Base 10 provides global economic and trade data for 121 countries and 20 aggregated regions in 65 sectors in the reference year 2014.[6] Those data are aggregated to 13 countries/regions and 16 sectors for the model simulations in this study, as is shown in Table 6. Countries/regions distinguish between developing and developed countries, the latter being the members of the Organisation for Economic Co-operation and Development (OECD) here.[7] On the other hand, the member states of the EU are aggregated to one region. The EU member states export and import within the EU; such trade is counted here as own bilateral trade of the EU region. Meanwhile, oil exporters are represented by the member states of the Gulf Cooperation Council (GCC). Sectors are classified according to the carbon content of products. Those sectors include four CO_2 emission commodities (coal; oil; gas; petroleum, coal products) and electricity, as well as chemicals, other mineral products, and transportation (which comprises air,

Table 6 Regional and sectoral aggregations

Countries/Regions	Sectors
Oceania	Coal
Japan	Oil
China	Gas
Korea	Petroleum, coal products
ASEAN	Electricity
India	Agriculture, forestry and fisheries
US	Paper products
North America	Chemicals
EU	Other mineral products
Other OECD	Metals
Russia	Motor vehicles and parts
GCC	Other machinery
Rest of world	Other manufacturing
	Construction
	Transportation
	Services

Source: Author's compilation based on GTAP 10 Data Base, GTAP.

[6] It must be noted that two key policy data need to be updated in the future. One is on CO_2 emissions; at this moment those have changed to some extent since 2014, either increasing or decreasing, depending on the country, as discussed before. Another group of data needing updating is tariff rates. Tariff reductions according to the implementation of recent trade agreements were not incorporated in tariff rates in 2014, which was before their implementation. Those major agreements include the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), the Regional Comprehensive Economic Partnership (RCEP) Agreement, and the Japan-EU Economic Partnership Agreement (EPA).

[7] Oceania is Australia and New Zealand, and North America is Canada and Mexico. Other OECD here consists of Chile, Colombia, Costa Rica, Iceland, Israel, Norway, Switzerland, Turkey, and the United Kingdom (UK). The EU includes the non-OECD member states, i.e., Bulgaria, Croatia, Cyprus, Malta, and Romania.

water, and other transport in the GTAP database).

The GTAP-E model is an extended version of the standard GTAP model[8] for study of the impact of climate policy through trade. It is built on the GTAP-E Data Base, which is included in the satellite data of the GTAP 10 Data Base, incorporating CO_2 emission data. The standard GTAP model is a multi-regional CGE model in which regional economies are linked through international trade. Products are distinguished by place of production, assuming imperfect substitution of goods and services among regions, which is known as the Armington assumption (Armington, 1969). In addition to private consumption, government consumption is endogenously determined, allocating regional income among private consumption, government consumption and saving, which is to be invested.

The GTAP model provides a few closure options to be chosen in consideration of the purpose of the study. In the model used in this paper, trade balance, and therefore national saving and investment balance, is not fixed assuming medium-term equilibrium. Capital balance is endogenous and international capital movement (in which the expected rates of return on capital are equalized among regions) is endogenously determined as well. Meanwhile, capital stock is also endogenous, incorporating capital accumulation effects and linking induced changes in income, saving, investment to capital stock. On the other hand, labor is adjusted among sectors within a region but is still exogenous at region-wide level, which means that the international movement of labor is not incorporated. It must be noted that the magnitudes of the estimated impacts of policy scenarios would vary depending on the theoretical structure of the model discussed above, and others, as touched upon later.

b) Scenarios and assumption

The main purpose of this study is to investigate the relative significance of climate and trade policies among a few possible scenarios, as follows. First, the impact of carbon tax and a CBAM will be compared. It is assumed that the CBAM is to be applied to imports but not exports, following the EU CBAM. On the other hand, the aim is to study the potential impact of a CABM applied to all goods and services, rather than to limited sectors in the EU CBAM, which could be extended to other sectors later. Second, the impact of carbon pricing will be compared among a few different scopes of regions taking initiatives: the EU; developed countries (the EU and the OECD countries); and the world. Third, the impact of a CBAM, which is trade related climate policy, will be

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[8] The standard GTAP model was initially documented in Hertel ed. (1997).

compared with that of trade liberalization, which is largely trade policy.

- Carbon pricing

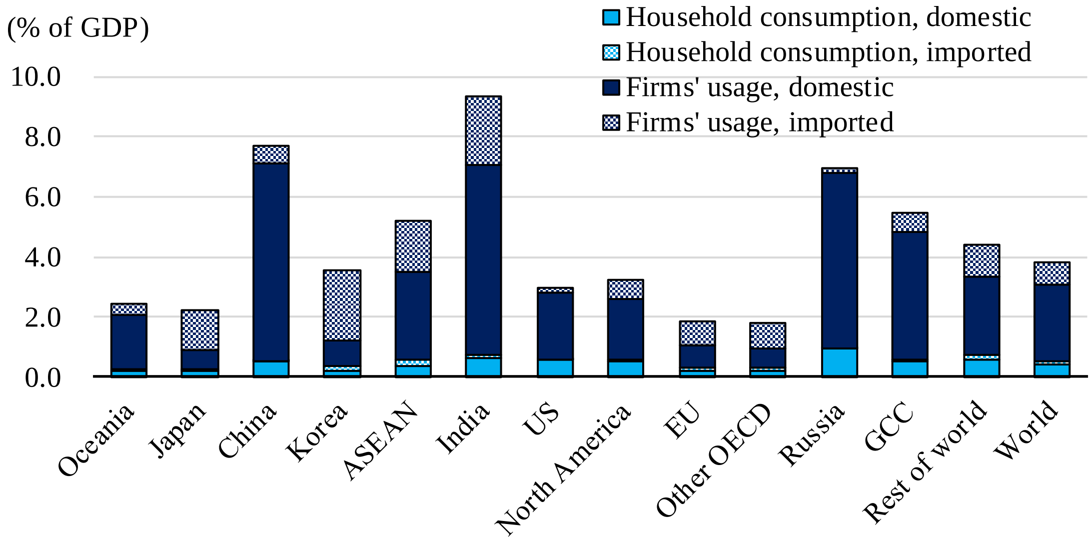
EU CTAX:	Carbon tax in the EU
EU +CBAM:	Carbon tax in the EU with a CBAM
OECD CTAX	Carbon tax in the EU and the OECD countries
OECD +CBAM:	Carbon tax in the EU and the OECD countries with a CBAM
Global CTAX:	Carbon tax in the world

- Trade liberalization

EU tariff:	Tariff removals by the EU from outside
OECD tariff;	Tariff removals by the EU and OECD countries from outside

A carbon tax rate of 100 USD per t CO_2 is assumed across all sectors and regions, which is in the upper range of meeting the Paris temperature target in 2030, indicated by WB (2017), as discussed before. The magnitudes of those ex-ante carbon taxes, measured in terms of per cent of GDP by region, are shown in Chart 3. Those are higher in developing countries, including India, China, and Russia, than in developed countries including Japan, the US and the EU, as is suggested by the differences in CO_2 emissions per GDP among countries, discussed before. Meanwhile, a breakdown of those tax payments between household final consumption and firms' intermediate usage, as well as between domestic and imported products, indicates that the bulk of CO_2 is emitted, and that carbon tax would be paid according to the firms' usage of domestic products. That said, more than half of those taxes would be paid in Japan, and close to half in the EU, according to firms' usage of imported products.

Chart 3 Composition of carbon tax payment



Source: Author's calculation based on GTAP 10 Data Base, GTAP.

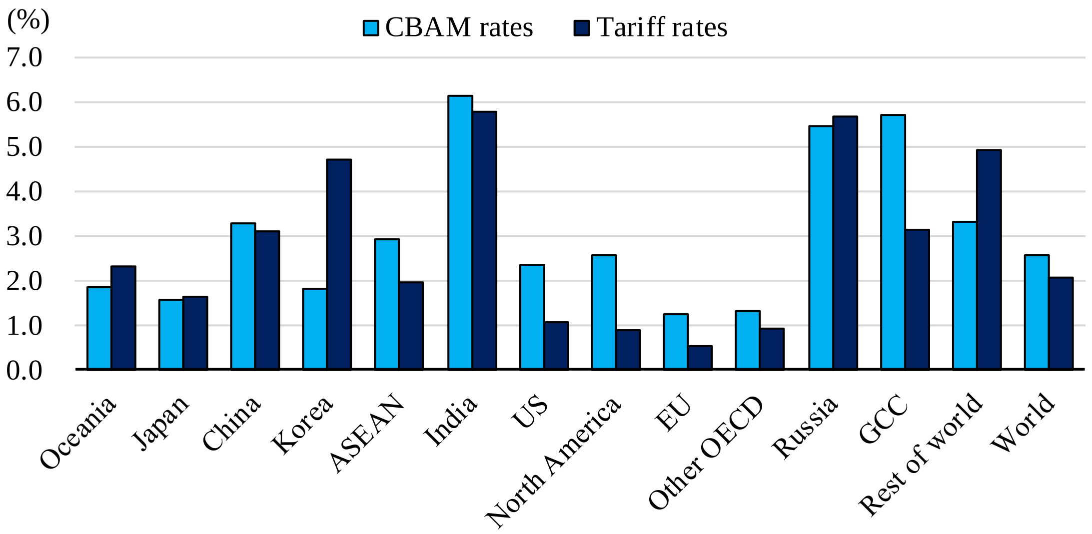
CBAM rates are calculated here based on the ratio of CO_2 emissions by firms over firms' production by regions and sectors, under the same level of assumption as the carbon tax rate above,[9] as follows. Household CO_2 emissions and carbon tax payments are not included because those price costs are not reflected in the market prices of trading products. What is included in exogenous CBAM rates here is the corresponding direct price costs of carbon tax, for example in electricity and transportation using fossil fuels. On the other hand, the impact of indirect price costs, for example in manufacturing using electricity, is not incorporated, and is beyond the scope of this study.

$$CBAMR_{ir} = CTAXR * \frac{CO2F_{ir}}{VMF_{ir}}$$

$CBAMR_{ir}$:	CBAM rate in sector (i) from region (r)
$CTAXR$:	Carbon tax rate
$CO2F_{ir}$:	CO_2 emissions by firms in sector (i) in region (r)
VMF_{ir}:	Firms' production in sector (i) in region (r)
$CO2F_{ir} = \sum_c CO2F_{cir}$:	CO_2 emissions from firms' usage of commodity (c) in sector (i) in region (r)
$VMF_{ir} = \sum_c VMF_{cir}$:	Firms' usage of commodity (c) in sector (i) in region (r)

The calculated CBAM rates above are compared with tariff rates by region and sector in Charts 4-A and 4-B, respectively. By region, CBAM rates also vary widely

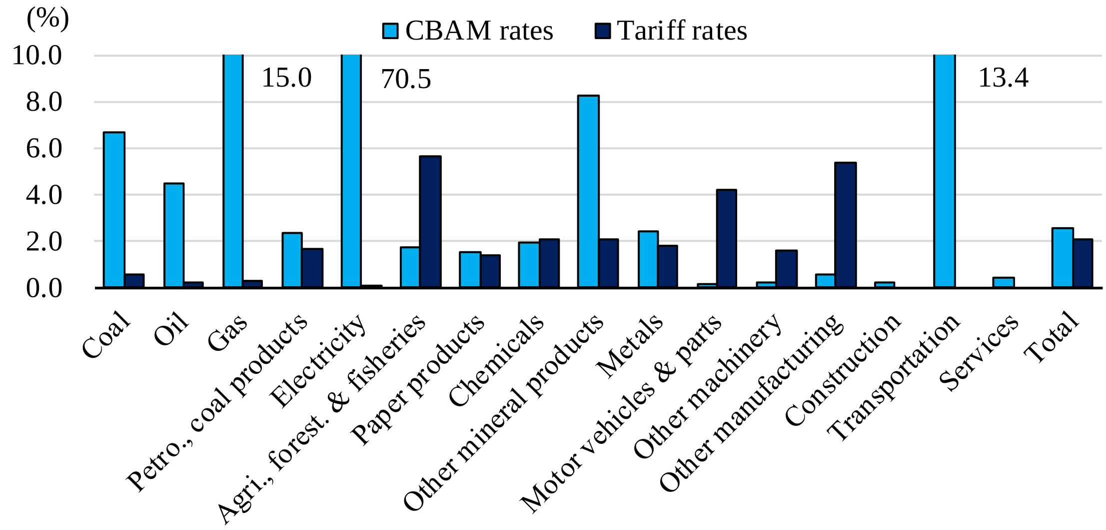
Chart 4-A CBAM rates and tariff rates by region



Source: Author's calculations based on GTAP 10 Data Base, GTAP.

[9] The EU ETS price rate was around 86.5 USD per t CO_2 as of April 2022, as is shown in Chart 2; the EU CBAM price would be applied on the basis of that price.

Chart 4-B CBAM rates and tariff rates by sector



Source: Author's calculations based on GTAP 10 Data Base, GTAP.

between developed and developing countries, similar to the case of carbon tax payment above. On the other hand, calculations here indicate that a global average CBAM rate (2.6%) is not so different from that of a tariff rate (2.1%.)[10] under the current assumption of a carbon tax rate. That said, those rates are relatively higher than tariff rates in the US and the EU. By sector, global average CBAM rates are extremely higher in electricity, followed by gas and transportation, than in other sectors. On the other hand, CBAM rates are lower than tariff rates in agriculture, forestry, and fisheries; motor vehicles and parts; and other manufacturing in which higher than average tariff rates among sectors remain.

3) Estimated results

a) Impact on CO_2 emissions

The impact of carbon pricing in the EU and OECD countries would be limited compared with that of a global initiative, as is shown in Table 7-A. If the EU imposed a carbon tax, it is estimated that CO_2 emissions would be reduced in the EU by 25.31%, but by 2.52%. in the world. If the tax were extended to cover OECD, CO_2 emissions reductions in the OECD countries would range from 26.41% in Japan to 44.26% in the US, with much smaller associated reductions in non-OECD countries, ranging from 2.61% to 6.23%. That said, global CO_2 emissions are estimated to be reduced by 16.43%,

[10] A CBAM would be applied not just to goods but also to service sectors. Therefore, calculation of the average tariff rates by region and for all sectors here includes service sectors as well, where no tariffs are imposed as they are on goods. The discrepancy between a global average CBAM rate and the tariff rate on goods here is around 0.1%, which is smaller than that mentioned above.

Table 7-A Impact of carbon pricing on CO_2 emissions

(%)

	EU CTAX	EU +CBAM	OECD CTAX	OECD +CBAM	Global CTAX
Oceania	-0.23	-0.24	-39.84	-39.23	-42.89
Japan	-0.22	0.19	-26.41	-27.11	-30.75
China	-0.43	-0.33	-3.39	-3.58	-58.40
Korea	-0.11	0.24	-32.73	-33.58	-36.19
ASEAN	-0.12	-0.58	-3.45	-5.21	-45.64
India	-0.32	-0.43	-2.93	-3.59	-52.88
US	0.18	0.04	-44.26	-43.90	-45.20
North America	0.02	0.09	-37.19	-35.51	-40.70
EU	-25.31	-25.16	-26.67	-26.17	-29.80
Other OECD	0.85	0.41	-29.28	-28.95	-33.06
Russia	-0.25	-0.78	-3.84	-5.25	-42.45
GCC	-0.78	-1.21	-6.23	-8.19	-52.86
Rest of world	0.26	0.12	-2.61	-3.01	-45.36
World	-2.52	-2.58	-16.43	-16.64	-46.61

Source: Author's simulations.

far smaller than the impact of a global carbon tax, 46.61%. It is not surprising that the contributions of carbon tax in the EU and OECD countries to reduction of global CO_2 emissions could be proportional to the share of CO_2 emissions in the world by region, and lower in developed countries than developing countries. It is suggested if a carbon tax were introduced in a strong enough form worldwide, it would be effective for substantially reducing global CO_2 emissions, particularly if it included developing countries.

The estimated impact of a global carbon tax at a common rate across regions would still vary among regions, as shown in Table 7-A. CO_2 emissions reductions would be smaller in Japan and the EU, where carbon tax payment would be lighter than the global average, but larger in China, India and Russia, where carbon tax payment would be heavier than the global average. CO_2 emissions would be reduced in regions where carbon pricing was introduced. Meanwhile, impact on CO_2 emissions in the EU would broadly remain unchanged among the various regional scopes of carbon tax. The above two findings indicate that for reduction of CO_2 emissions, introducing carbon tax in own regions would be essential.

On the other hand, the impact of a CBAM in both the EU and OECD countries would be minor compared with that of a carbon tax. It is suggested that carbon pricing at home would be more efficient for reduction of CO_2 emissions than carbon pricing at the border, which would affect trade partners abroad.

b) Impact on economy

However, the adverse impact of a wider carbon tax on economy would be serious, as can be seen in Table 7-B. World real GDP is estimated to contract by 0.98% under carbon tax in the EU, by 4.48% under an EU and OECD carbon tax, and by 11.30% under a global carbon tax. It should be noted that, according to World Economic Outlook Database, IMF, the magnitudes of those contractions of real GDP would be larger than those in the 2009 depressions (2.0%) resulting from the global financial crisis, and those in 2020 (3.4%) resulting from the COVID-19 pandemic.

Moreover, the impact of a global carbon tax on real GDP is estimated to vary by region. It would also be larger in developing countries including China, India, and Russia than in developed countries including Japan, the US, and the EU. This could be explained primarily by higher carbon price costs in developing countries, as in the case of impact on CO_2 emissions.

Another factor that could differentiate the magnitudes of adverse real GDP impact among regions is possible international movement of capital. In the regions where international capital inflows would be expected, capital formation could mitigate the adverse impact of carbon tax, though on the other hand it would pose a trade deficit. In contrast, the adverse impact would be exaggerated in those regions where capital outflows would be expected. In reality the likely impact of carbon pricing on economy would be

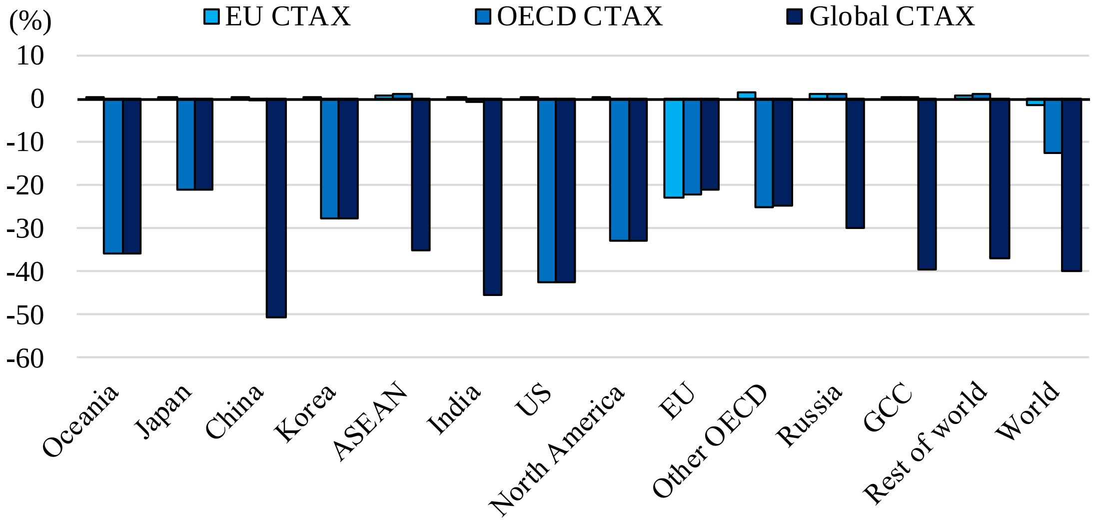
Table 7-B Impact of carbon pricing on real GDP

(%)

	EU CTAX	EU +CBAM	OECD CTAX	OECD +CBAM	Global CTAX
Oceania	-0.54	-0.47	-6.28	-6.18	-11.22
Japan	-0.48	-0.29	-6.73	-7.00	-12.19
China	-0.43	-0.31	-2.91	-2.89	-15.69
Korea	-0.41	-0.23	-7.06	-7.51	-11.87
ASEAN	-0.72	-0.67	-4.50	-4.98	-16.06
India	-0.36	-0.35	-2.37	-2.56	-13.69
US	-0.15	-0.13	-3.00	-3.00	-4.60
North America	-0.50	-0.45	-6.46	-6.17	-11.49
EU	-3.01	-3.26	-5.77	-5.83	-11.12
Other OECD	-0.69	-0.80	-5.74	-5.78	-11.28
Russia	-1.26	-0.33	-5.08	-5.04	-18.11
GCC	-1.19	-1.32	-6.51	-7.30	-22.31
Rest of world	-0.63	-0.72	-3.57	-4.14	-13.26
World	-0.98	-0.99	-4.48	-4.61	-11.30

Source: Author's simulations.

Chart 5 Reductions of CO_2 emissions per GDP



Source: Author's simulations.

dependent on the flexibility of international capital flows.[11]

The relative significance of carbon tax can be seen by comparing the benefits of reductions in CO_2 emissions and the costs of contractions in real GDP. The global costs of reducing CO_2 emissions would be relatively cheap if the regional scopes of carbon tax were extended, as is suggested by the reductions of CO_2 emissions per GDP shown in Chart 5. Global per GDP CO_2 emissions are estimated to decline by 1.56% under an EU carbon tax, by 12.52% under an EU and OECD carbon tax, and by 39.80% under a global carbon tax. This means that carbon tax would be more efficient for reducing CO_2 emissions under wider initiatives. The efficiency of carbon pricing above would also vary among regions. The estimated reductions of CO_2 emissions per GDP are generally larger in developing countries than those in developed countries, whereas more efficient contributions towards CO_2 emissions reduction would be expected from developing countries than from developed countries.

In addition to the variation in impact of carbon pricing by region, variation by sector, shown in Table 8, would be a matter of concern. World production under a global carbon tax is estimated to decrease the most in coal, followed by oil; gas; petroleum, coal products; and electricity. It would be relatively small in agriculture, forestry, and fisheries but larger in construction. Among the remaining manufacturing sectors, production would

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[11] Kawasaki (2018) conducted a sensitivity analysis of capital formation mechanism in a CGE model for the case of common tariff rate hikes among regions, examining the effects of international capital flows caused by changes in expected rates of return on capital.

Table 8 Impact of carbon pricing on world production, by sectors

(%)

	EU CTAX	EU +CBAM	OECD CTAX	OECD +CBAM	Global CTAX
Coal	-3.18	-3.20	-15.63	-15.96	-51.65
Oil	-1.67	-1.84	-9.07	-9.55	-22.44
Gas	-2.45	-2.93	-12.20	-12.43	-35.34
Petro., coal products	-1.72	-1.90	-8.88	-9.35	-22.35
Electricity	-2.62	-2.65	-12.39	-12.68	-29.36
Agri., forest. & fisheries	-0.49	-0.47	-2.43	-2.52	-7.53
Paper products	-0.97	-0.97	-4.21	-4.30	-10.89
Chemicals	-0.92	-0.88	-4.38	-4.44	-13.28
Other mineral products	-1.16	-1.07	-6.24	-6.35	-21.36
Metals	-1.20	-1.15	-6.31	-6.41	-19.21
Motor vehicles & parts	-1.04	-1.06	-5.48	-5.65	-15.23
Other machinery	-1.30	-1.27	-6.46	-6.56	-17.93
Other manufacturing	-0.73	-0.75	-3.30	-3.43	-8.82
Construction	-1.56	-1.55	-8.16	-8.36	-21.39
Transportation	-1.38	-1.46	-5.39	-5.60	-13.34
Services	-0.90	-0.89	-3.81	-3.88	-9.45

Source: Author's simulations.

decrease more in other mineral products and metals than in motor vehicles and parts, and other machinery. Similar differences in estimated impact on production by sector are observed under the EU and OECD carbon pricing initiatives, though those absolute magnitudes would be much smaller than those under global carbon pricing.

The sizable adverse impact of carbon pricing on economy shown above would not be acceptable in realty. Efforts have been made to reduce CO_2 emissions by means of alternative climate policies, which include saving energy, and the development of renewable energy without using fossil fuels. In implementing those alternative policies, the utilization of carbon pricing tax revenues could have been anticipated. That said, those possible magnitudes are estimated to be much smaller than the impact on income, as is shown in Table 9. In the case of introduction of a carbon tax and a CBAM in the EU and OECD countries, the ex-post real tax revenues of the OECD countries under carbon pricing[12] are estimated to account for 1.69% of ex-ante GDP, against a 5.02% contraction of real GDP. Variations in those estimated tax revenues by region, ranging between 1.44% and 2.79% of GDP, would also be smaller than the difference between the magnitudes of

[12] Those figures are based on the reduced levels of CO_2 emissions after the introduction of carbon pricing, estimated by model simulations, therefore they differ from ex-ante carbon tax payments based on CO_2 emissions in 2014, before the introduction of carbon pricing, as shown in Chart 3. Real tax revenue figures are calculated here using a GDP deflator, which is estimated to rise by 2.76% in the OECD countries on average.

Table 9 Impact on tax revenues

	Real GDP (%)	Real tax revenues (% of GDP)			
	OECD +CBAM	+CBAM	(CTAX)	(CBAM)	Tariff
Oceania	-6.18	1.65	(1.48)	(0.17)	-0.45
Japan	-7.00	1.81	(1.59)	(0.22)	-0.32
Korea	-7.51	2.79	(2.28)	(0.51)	-1.99
US	-3.00	1.72	(1.62)	(0.10)	-0.16
North America	-6.17	2.13	(2.02)	(0.11)	-0.28
EU	-5.83	1.54	(1.33)	(0.21)	-0.21
Other OECD	-5.78	1.44	(1.24)	(0.21)	-0.28
OECD	-5.02	1.69	(1.52)	(0.17)	-0.27

Source: Author's simulations.

carbon pricing tax revenues and real GDP shown above. Meanwhile, the contribution of a CBAM to tax revenues (0.17% of GDP) would be much smaller than that of a carbon tax (1.52% of GDP) and could not be much larger than possible losses of tariff payments (0.27% of GDP) due to the impact of trade liberalization, discussed later.

c) Impact on trade

Under an EU CBAM, imports by the EU and then exports of the EU's trade partners would decrease due to higher price costs. The impacts on the exports of trade partners would vary because of variation in the structure of trade and industry among regions, and moreover, differences in CBAM rates by region and sector, as discussed earlier. Apart from energy commodities including fossil fuels and electricity, as is shown in Table 10-A, bilateral exports to the EU from most regions, except Japan and GCC, in agriculture, forestry and fisheries are estimated to decrease. Exports of paper products would also decrease, except from Korea and other OECD; in chemicals except from Korea, the US and other OECD; in other mineral products except from Oceania. On the other hand, bilateral exports to the EU from Russia and GCC would decrease but would increase from other regions in motor vehicles and parts, other machinery, and other manufacturing. Meanwhile, EU internal exports would increase in the first group of sectors above, and decrease in the second group. Exports in metals would increase in the OECD countries, but would decrease in the non-OECD countries.

What does matter here from the perspective of price competitiveness of trade among regions is variation among regional CBAM rates. Under the current CGE model framework, the substitution of goods and services among regions is structured in two steps, beginning with the allocation of domestic and imported products. All regions and sectors would lose price competitiveness with respect to the EU at the border. The second step is the allocation of products among the different regional sources of imports. The

Table 10-A Changes in bilateral exports of non-energy goods to EU

(%)

	AFF	PPP	CHM	NMM	MET	MVH	OME	OMF
Oceania	-3.48	-1.27	-5.49	4.15	-11.70	4.01	4.39	2.66
Japan	2.05	-3.32	-1.03	-10.09	2.57	2.95	2.74	0.77
China	-3.34	-4.76	-6.47	-17.01	-11.48	2.43	2.46	0.65
Korea	-2.14	2.57	4.84	-6.41	1.04	2.35	2.67	2.63
ASEAN	-2.90	-13.93	-3.32	-28.07	-4.33	3.36	3.31	0.94
India	-4.97	-14.80	-8.65	-52.39	-54.07	4.66	4.23	2.84
US	-3.21	-2.88	0.35	-7.71	1.59	3.15	2.89	1.63
North America	-8.98	-3.35	-5.55	-8.46	-0.17	3.88	3.28	3.05
EU	0.23	-0.18	0.24	5.77	0.48	-1.64	-3.15	-1.32
Other OECD	-2.64	2.22	4.16	-3.43	5.17	2.49	3.02	2.96
Russia	-12.18	-2.68	-25.47	-21.21	-19.10	-0.68	-4.43	-0.21
GCC	6.54	-50.06	-48.23	-44.90	-19.90	-1.44	-45.49	-34.42
Rest of world	-1.42	-4.04	-9.20	-9.10	-15.34	4.00	2.82	3.56
World	-0.95	-0.40	-0.57	-3.78	-1.71	-0.68	-0.57	0.03

Note: Abbreviations stand as follows: AFF for agriculture, forestry and fisheries; PPP for paper products; CHE for chemicals; NMM for other mineral products; MET for metals; MVH for motor vehicles and parts; OME for other machinery; and OMF for other manufacturing.
Source: Author's simulations.

EU's trade partners would compete with each other, depending on the varying price costs generated by a CBAM possibly generating winners and losers.

The magnitudes of changes in overall regional exports by sector would be

Table 10-B Changes in regional exports of non-energy goods

(%)

	AFF	PPP	CHM	NMM	MET	MVH	OME	OMF
Oceania	-0.38	0.26	0.33	0.17	0.68	0.42	1.15	0.43
Japan	-0.62	-0.26	0.15	-1.06	0.12	0.33	0.27	-0.33
China	-1.08	-0.63	-0.38	-2.14	-1.25	0.60	0.60	-0.20
Korea	-0.59	-0.14	0.74	-0.76	-0.11	0.35	0.22	-0.25
ASEAN	-0.56	0.11	0.57	-1.36	0.55	0.90	1.13	0.37
India	-0.39	0.21	0.46	-10.63	-5.75	1.96	2.24	1.25
US	-0.21	0.13	0.63	-0.98	0.86	0.90	1.19	0.42
North America	-0.36	0.55	1.08	-1.02	1.39	0.80	1.07	0.79
EU	-0.34	-1.12	-1.60	1.12	-1.27	-1.84	-3.09	-1.95
Other OECD	-1.12	0.39	1.60	-0.80	1.21	1.04	1.16	0.86
Russia	-3.11	-2.52	-10.96	-9.46	-7.01	-1.91	-3.94	-2.40
GCC	0.93	1.24	-2.03	-8.55	1.46	1.92	-0.95	0.13
Rest of world	0.16	0.70	0.50	-0.96	-0.19	1.85	2.33	1.77
World	-0.34	-0.47	-0.52	-0.99	-0.48	-0.41	-0.23	-0.28

Note: For abbreviations, see the footnote to Table 10-A.
Source: Author's simulations.

smaller than that on a bilateral basis. That said, the stylized features mentioned above could still be suggested, as is shown in Table 10-B. Exports of agriculture, forestry and fisheries and other mineral products would still decrease from most regions, but exports of motor vehicles and parts, other machinery and other manufacturing would increase from most regions. On the other hand, exports of paper products and chemicals would decrease from a limited number of regions including China and Russia, and exports of metals from China, India and Russia would decrease. It would be worthwhile to study the impact of a CBAM and carbon pricing in much greater detail, by region and by sector.

By region, again the impact on total regional trade would be somewhat smaller than that on a bilateral basis, as a result of the general equilibrium mechanism of income and price effects, including trade creation and diversion effects among regions, as discussed above. That said, as is shown in Table 11-A, it is estimated that exports would decrease the most in the EU under an EU CBAM. As a result, real GDP would primarily decrease in the EU. On the other hand, the impact on trade and economy in the other regions would still vary depending on variation in CBAM rates by region. Exports are estimated to increase in Japan but decrease in China and India.[13]

Meanwhile. the impact of a CBAM on aggregated trade would also be smaller than that of carbon tax at macro level. That said, it would be noted that the impact on real

Table 11-A Trade effects of EU carbon pricing and removal of tariffs

	Import volume (%)			Export volume (%)			Real GDP (%)		
	CTAX	CBAM	Tariff	CTAX	CBAM	Tariff	CTAX	CBAM	Tariff
Oceania	-1.06	-0.09	0.80	-0.28	-0.04	0.36	-0.54	0.07	0.13
Japan	-0.66	0.26	0.35	-0.56	0.13	0.23	-0.48	0.20	0.06
China	-0.82	0.17	0.92	-0.16	-0.02	0.55	-0.43	0.12	0.12
Korea	-0.51	0.23	-0.09	-0.35	0.12	-0.04	-0.41	0.18	-0.05
ASEAN	-0.84	-0.03	0.18	-0.53	0.02	0.10	-0.72	0.06	0.05
India	-0.50	-0.29	0.30	0.00	-0.28	0.22	-0.36	0.01	0.04
US	-0.62	-0.19	0.35	-0.25	-0.18	0.27	-0.15	0.02	0.01
North America	-0.69	0.05	0.02	-0.33	0.22	-0.01	-0.50	0.05	0.00
EU	-4.62	-1.22	0.54	-5.76	-1.49	0.82	-3.01	-0.24	0.16
Other OECD	-1.44	-0.73	-0.10	-0.81	-0.35	-0.10	-0.69	-0.11	-0.02
Russia	-3.14	0.91	0.70	-1.30	1.01	0.26	-1.26	0.93	0.11
GCC	-2.02	-0.90	0.43	-0.99	-0.38	0.22	-1.19	-0.13	0.16
Rest of world	-1.20	-0.86	0.29	-0.43	-0.51	0.17	-0.63	-0.09	0.06
World	-2.06	-0.54	0.39	-2.06	-0.54	0.39	-0.98	-0.01	0.07

Source: Author's simulations.

[13] Exports from Russia are estimated to increase, since under the current simulations oil and gas exports would more than offset the above decreases in non-energy goods.

Table 11-B Trade effects of EU and OECD carbon pricing and removal of tariffs

	Import volume (%)			Export volume (%)			Real GDP (%)		
	CTAX	CBAM	Tariff	CTAX	CBAM	Tariff	CTAX	CBAM	Tariff
Oceania	-9.40	-0.59	1.02	-8.08	-1.06	0.97	-6.28	0.10	0.28
Japan	-9.53	-0.96	0.66	-12.21	-1.56	0.99	-6.73	-0.26	0.07
China	-5.45	-0.25	3.30	-0.97	-0.28	1.89	-2.91	0.02	0.52
Korea	-10.99	-1.61	5.92	-11.40	-1.88	5.74	-7.06	-0.45	3.66
ASEAN	-5.37	-0.87	1.06	-3.80	-0.37	0.66	-4.50	-0.49	0.38
India	-3.62	-1.18	1.11	-0.63	-0.94	0.74	-2.37	-0.19	0.20
US	-2.16	-0.58	0.65	-9.74	-1.09	1.57	-3.00	0.01	0.02
North America	-5.48	0.28	0.86	-7.07	-0.37	1.41	-6.46	0.29	0.09
EU	-7.71	-0.49	0.25	-8.32	-0.72	0.53	-5.77	-0.06	0.12
Other OECD	-7.15	-0.59	0.74	-7.71	-1.11	1.03	-5.74	-0.04	0.21
Russia	-8.84	-0.90	1.35	-3.78	-0.22	0.53	-5.08	0.04	0.25
GCC	-9.05	-2.85	1.11	-5.15	-1.39	0.57	-6.51	-0.79	0.52
Rest of world	-5.13	-2.70	1.09	-2.21	-1.55	0.65	-3.57	-0.56	0.23
World	-6.33	-0.91	1.09	-6.33	-0.91	1.09	-4.48	-0.13	0.26

Source: Author's simulations.

GDP reflects the net results of the balance of changes in exports and imports, which could offset each other. The gross impact of carbon pricing on trade could be larger than that on production and income. World real GDP is estimated to contract by 0.01% under a CBAM, much less than under a carbon tax (0.98%). On other hand, world trade is estimated to decrease by 0.54% under a CBAM, which is around a quarter of the decrease under a carbon tax (2.06%).

If the application of a CBAM were extended to include the OECD countries, imports and then exports would decrease universally, both in the OECD and non-OECD countries as a result of induced income effects in addition to price effects, as is shown in Table 11-B. World trade and real GDP are estimated to decrease more than they would under the EU CBAM. That said, the adverse impact on the EU in terms of exports, imports and real GDP would be mitigated relative to that under the EU CBAM. On the other hand, real GDP would in turn decrease in both the OECD countries including Japan and the non-OECD countries including India. Appropriate policy coordination among countries would be useful if an adverse impact of policy measures on economy and trade were expected.

d) Impact of trade liberalization

When the EU removes import tariffs from other regions, exports would be boosted in almost all regions. Tariff removals by the EU are indicated to offset the adverse impact of a CBAM on trade and economy in a few regions. It may be noted that the EU would benefit from own unilateral trade liberalization, despite the fact that the EU would lose from the EU CBAM, as discussed above. World trade is estimated to increase by 0.39%, which is not so much smaller than the magnitude of the decrease in trade under the EU CBAM above. World real GDP is also estimated to increase by 0.07% under the EU tariff removals, which is more than it would decrease under the EU CBAM. On the other hand, global CO_2 emissions would also increase by 0.06% in line with an increase in real GDP under the EU tariff removals—which accounts for the magnitude of those decreases under the EU CBAM (0.06%)—but again much smaller than those under the EU carbon tax (2.52%), as discussed before.

Tariff removals by the EU and OECD countries would more or less offset the adverse impact of the EU and OECD CBAM, depending on the region. World trade is estimated to increase by 1.09% under tariff removals, more than offsetting its decrease by 0.91% under a CBAM. World real GDP would also be boosted by 0.26% under tariff removals, which is twice the size of its decrease under a CBAM (0.13%). On the other hand, global CO_2 emissions are estimated to increase by 0.30% under tariff removals; once again those would be larger than the decreases under a CBAM (0.21%) but less than double the case of real GDP as above, and needless to say, far smaller than those under the EU and OECD carbon tax (16.43%), as discussed before. All in all, a balanced study of the relative significance of the impact of alternative policy scenarios on economy, trade and environment would be worthwhile.

IV. Conclusions

Global GHG and CO_2 emissions have continued to increase, largely because of persistent increases in developing countries including China and India. Achievements toward GHG emissions reduction under the Paris Agreement have fallen far short of the targets. That said, per capita CO_2 emissions in the US have continued to be the highest among major countries. NDCs have varied among parties targeting absolute or GDP-relative GHG emissions. An appropriate measurement for setting GHG emissions reduction targets would still be one key climate policy agenda item. Meanwhile, carbon pricing has been implemented but remains limited, covering less than a quarter of global GHG emissions. In the meantime, the EU has agreed to introduce a CBAM.

The results of quantitative studies using a CGE model suggest that the impact of carbon pricing in the EU and OECD countries would be limited compared with that of a global initiative. Carbon tax, once introduced in a strong form worldwide (in particular including developing countries) would be effective for substantially reducing global CO_2

emissions. However, the adverse economic impact of carbon pricing would be serious and much larger than the magnitude of possible carbon tax revenue. Meanwhile, the economic impacts would be larger in developing counties than in developed countries; and in fossil fuels and electricity sectors, followed by metals and construction, than in other sectors. On the other hand, the impact of a CBAM would be minor compared with that of a carbon tax, regardless of the coverage of economies. Carbon pricing at home would be more efficient for reducing CO_2 emissions than that at the border, affecting abroad. Trade effects of a CBAM could more or less be offset by trade liberalization in terms of both adverse impact on economy and trade, and reduction of CO_2 emissions.

The impact of carbon pricing on economy and trade would vary by region as well as by sector. Appropriate policy coordination among countries would be useful when an adverse impact of policy measures on economy and trade is expected. Climate and trade policies should be well-designed and based on sound quantitative analysis. It would be of value to conduct a balanced study of the relative significance of the impact of various alternative policy scenarios on economy, trade and environment.

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