The role of international trade in climate change

Abstract

This paper examines the role of international trade on climate change. The impact of climate change varies by crop and location causing production and trade patterns to evolve and adapt given the new conditions.

In particular, we look to implement climate change effects such as sea level rise on the availability of land, productivity changes caused on wheat, paddy rice, and other grains, and productivity changes caused on value added.

Trade acts a conduit that could help ameliorate the negative of climate change, but it could also lead to increase the emissions of greenhouse gas emissions. We will simulate trade restrictions to help evaluate the relevance of trade when climate change shocks are considered using the GTAP-E model, which allows for the tracking of carbon dioxide emissions for each simulation in addition to welfare changes and their distributional impact across countries.

Introduction

This paper examines the role of international trade on climate change. The impact of climate change varies by crop and location causing production and trade patterns to evolve and adapt given the new conditions. International trade, however, is regulated by country-policy instruments that limit the trade response to the changing environmental conditions.

For this analysis we chose the GTAP framework because it considers the interactions of the global economy through bilateral trade and tariffs. It also provides comprehensive representation each country's economy. GTAP contains key sectoral detail on agricultural sectors, which are directly affected by climate change. The sectors in the GTAP Data Base are derived from the input-output (IO) tables at its core, but not all input-output (IO) tables in GTAP contained the 12 agricultural sectors. During GTAP's construction, these sectors are disaggregated when needed using FAO data as explained by Peterson (2016). Furthermore, the GTAP Data Base also considers agricultural domestic support, which is based on the OECD's Producer Support Estimates database. During the latter, agricultural production is targeted to improve the representation of agriculture and its support, which also facilitates the reconciliation with macroeconomic and trade data.

Data and Model

In this paper we use GTAP 10a, reference year 2014, which includes agricultural production of greater number of countries such as India (Aguiar et al. 2019). Chepeliev and Aguiar (2018) had identified that one of the limitations of the current approach to APT is that it misses developing countries and some major agricultural producers like India, which is included in 10a. Our aggregation consists of 13 regions and 16 sectors as described in Table 1. For the simulations we use the GTAP-E model, release 6 (McDougall and Golub, 2009). This extension of GTAP is used to evaluate costs of abatement and to assess the spill-over effects of greenhouse gases (GHG) abatement policies via international trade and sectoral interaction as such, GTAP-E incorporates carbon emissions from the combustion of fossil fuels which we are interested to report as part of our simulation results.

Table 1. Aggregation details

Countries	Sectors
China, P.R.	Paddy Rice
Indonesia	Wheat
Rest of East Asia	Other grains (maize)
India	Rest of Agriculture (including forestry and fishing)
Rest of South Asia	Coal
Rest of Europe and Central Asia	Oil
Middle East and North Africa	Gas and distribution
Sub-Saharan Africa	Oil products
Brazil	Electricity
Rest of Latin America and Caribbean	Energy intensive industries
European Union	Food
United States	Other industries
Rest of high-income	Other transport
	Air transport
	Water transport
	Other services

We run several scenarios based on the summary estimates of climate change impacts by Roson and Sartori (2016), which are convenient to use with the GTAP framework. Roson and Sartori (2016) perform a series of meta-analyses to summarize the results of the literature. In particular, we look to implement climate change effects such as sea level rise on the availability of land, productivity changes caused on wheat, paddy rice, and other grains, see Table 2.

Table 2. Calibrated shocks of an increase in temperature of +3°C by 2050

Aggregate regions	% change in land stock due to sea level rise	% variation in multi-factor productivity		
		Maize	Wheat	Rice
China, P.R.	-0.001	-4.68	-8.46	-2.23
Indonesia	-0.020	-9.63	-19.19	-3.88
Rest of East Asia	-0.015	-8.05	-13.40	-3.33
India	-0.001	-6.63	-12.69	-2.88
Rest of South Asia	-0.001	-6.06	-10.47	-2.79
Rest of Europe and Central Asia	-0.004	-2.17	-2.87	-1.21
Middle East and North Africa	-0.003	-5.20	-9.51	-2.52
Sub-Saharan Africa	-0.001	-8.57	-14.50	-3.53

Aggregate regions	% change in land stock due to sea level rise	% variation in multi-factor productivity		
		Maize	Wheat	Rice
Brazil	-0.001	-7.08	-13.66	-3.03
Rest of Latin America and Caribbean	-0.008	-6.25	-10.92	-3.32
European Union	-0.004	-2.86	-4.22	-1.88
United States	-0.003	-4.45	-7.98	-2.15
Rest of high-income	-0.013	-2.78	-5.42	-2.33

In addition, to the climate change shocks, using the standard closure with full employment of factor endowment assumption, we consider different ways to affect trade in the model: we change the closure to restrict exports, we also fix the trade balance, and lower the trade elasticities, we increase tariffs by 30 percent, and then set tariffs at 30 percent, we also run climate change scenarios with a trade liberalization scenario in which import and export taxes are eliminated. In addition, instead of the sea level raising effect on land we simulate shocks to the productivity of land due to climate change using the shocks by Johnson et al. (2020). Table 3 summarizes the scenarios of this study.

Table 3. Scenarios run in this study

Scenarios	Land Availability	Productivity	Tariffs	Closure
Climate Change based on Roson and Sartori (2016) [CC_RS]	Reduction shock	Rice, Wheat, Grains shocks	No shock	Standard
+ fixed exports			Tariffs endogenous	Exports exogenous
+ fixed trade balance			No shock	Non-standard
+ reduce elasticities by half			No shock	Standard
+ raise power of tariffs by 30%			Increase	Standard
+ target tariffs to 30%			Increase	Standard
+ trade liberalization			Decrease	Standard
CC + Johnson et al.(2020)	No shock	+ land shock	No shock	Standard

Results

As a result of the climate change shocks (CC_RS), world production of rice and wheat decreased by about 1 percent, but not that of other grains, which actually marginally increases production.

Subtotal 1 isolates the effect of the shock to land. Subtotals 2, 3 and 4 capture shocks to rice, wheat and other grains, respectively.

Table 3. World output after climate change impact on shocked commodities (percentage change)

qow	Percentage change	Land contribution	Rice contribution	Wheat contribution	Grains contribution
pdr	-0.677	-0.003	-0.196	-0.355	-0.122
wht	-0.602	0.00002	-0.135	-0.427	-0.040
gro	0.379	-0.0003	-0.010	-0.021	0.410

This aggregate results shows that the reduction of land as modelled here, will not affect wheat production, but that the productivity shocks, in particular that to wheat itself drives the reduction of wheat output. For other grains, the shocks to land and other products (rice and wheat) have a very minor effect, rather the productivity shock actually causes an increase in output. This result is driven by the countries/regions in the table below (for other countries there is a reduction in real output):

Table 4. Output of grains, after climate change impact on selected countries/regions (percentage change)

qo[gro*]	(Sim)	Subtotal 1	Subtotal 2	Subtotal 3	Subtotal 4
CHN	2.20	0.0002	-0.05	-0.07	2.32
ECA	1.52	-0.0007	0.08	-1.02	2.46
E28	1.39	0.0010	0.16	0.00	1.23
USA	0.44	0.0008	0.13	0.09	0.22
XHY	5.22	-0.0043	-0.20	-0.14	5.56

The positive effect in output can be decomposed by domestic sales and exports in the table 5. Domestic sales in China drive the increase in production of other grains as exports are marginally decreasing. Similarly, in the EU and High income countries there is an increase in domestic sales, but exports sales also contribute to the increase in other grains production. On the other hand, in ECA and the US it is exports sales that are driving the increase in production of other grains because domestic sales of ECA and USA decrease. In the countries that there is an increase in domestic sales (China, EU, and Other high income countries) this is driven by intermediate sales. In the case of the EU and High income countries there is also a small increase in private consumption.

Table 5. Decomposing output sales of grains for selected countries/regions (percentage change)

	Domestic Sales	Exports	Total effect
CHN	2.23	-0.03	2.20
ECA	-0.03	1.55	1.52
E28	0.48	0.90	1.38
USA	-0.10	0.54	0.44
XHY	1.29	3.94	5.23

In terms of product-country results, rice production in India drops by 1.29 %, in China by 0.26%, and in Indonesia it actually increases by 0.88%. Rice exports from the US increase (qxw), while exports from other Latin American and East Asian countries decrease. EU and China enter the top 5 exporters of paddy rice as a result of the climate change shocks. While still an important importer of rice, the EU reduces its rice imports as its production and exports have increased due to climate shocks.

Of the top wheat producers, there is increased production in EU28, China, but a decrease in the Middle East and North Africa region and India. Of the top wheat exporters, EU and high income countries increase real exports while US, in contrast, reduces its real exports as response to the climate shocks. All but two countries increase their wheat imports. Indonesia and High Income countries reduce their imports. MENA's wheat imports increase the most in absolute terms.

When reviewing the effect of all scenarios on greenhouse gas emissions (CO_2), see Figure 2, we observe that the level of emissions at the world level would increase by 7 Mt of CO2 due to climate change, relative to the base data. It would increase with more trade by 2200 Mt under the trade liberalization scenario. It also increases when tariffs are set at 30% by 386 Mt.

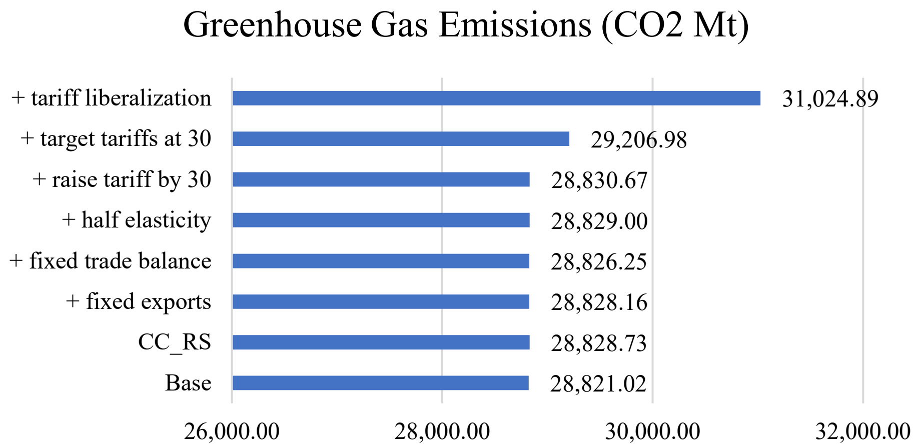

Figure 2. Greenhouse Gas Emissions (CO_2 Mt)
Source: Simulation results.

Figure 3 shows greenhouse gas emissions by country for each of the scenarios considered in this study. The trade liberalization increased the emissions for the globe, but looking into country changes, we see that under this scenario, China, MENA, and Brazil would decrease the level of emissions. The increase at the global level is driven by increases in Rest of East Asia, Europe and Central Asia, EU, US, and the rest of high income countries. On the contrary, targeting tariffs at 30% would increase driven by China, India, Europe and Central Asia, MENA and rest of Latin America to increase, while EU, US and rest of high income countries see a decline in the level of emissions.

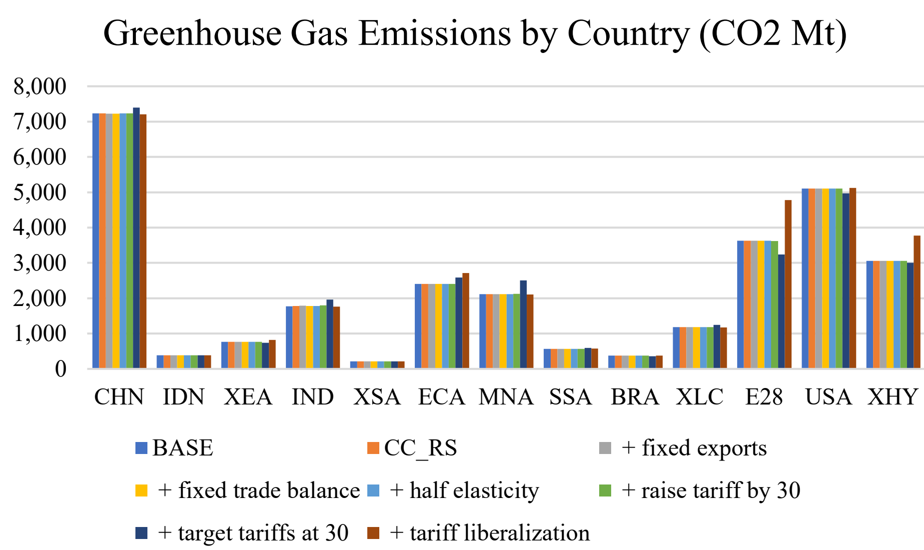

Figure 3. Greenhouse Gas Emissions by Country(CO_2 Mt)
Source: Simulation results.

With respect to the welfare effects of the simulations, see Figure 4, where the scenarios that considered climate change shocks and both trade liberalization and targeting tariffs at 30% are plotted on a secondary scale in due to the size of the response. From Figure 4, we see that climate change causes a decrease in welfare of about 47 billion USD driven by the loss in productivity. Only when tariffs are increased do we see welfare decreasing further and only improving when trade is liberalized and these are all related to the efficient allocation of resources.

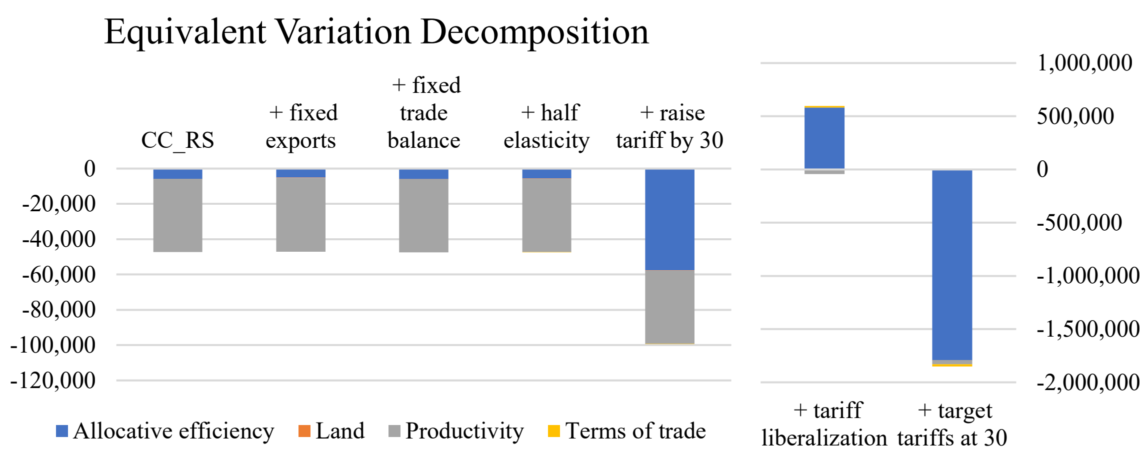

Figure 4. Equivalent variation decomposition (Million USD)
Source: Simulation results.

Figure 5 presents the geographic distribution of welfare. Climate change effects alone have a negative impact on all countries, with China, India, and MENA being those who lose the most. Similar geographic distributions take place with a fixed trade balance or reducing the trade elasticities. If export flows were not allowed to adjust in response to climate change shocks, causes the US, EU, India and Rest of High income countries to lose the most and this is driven by terms of trade effects, except the US although is still an important negative effect, see Table X.

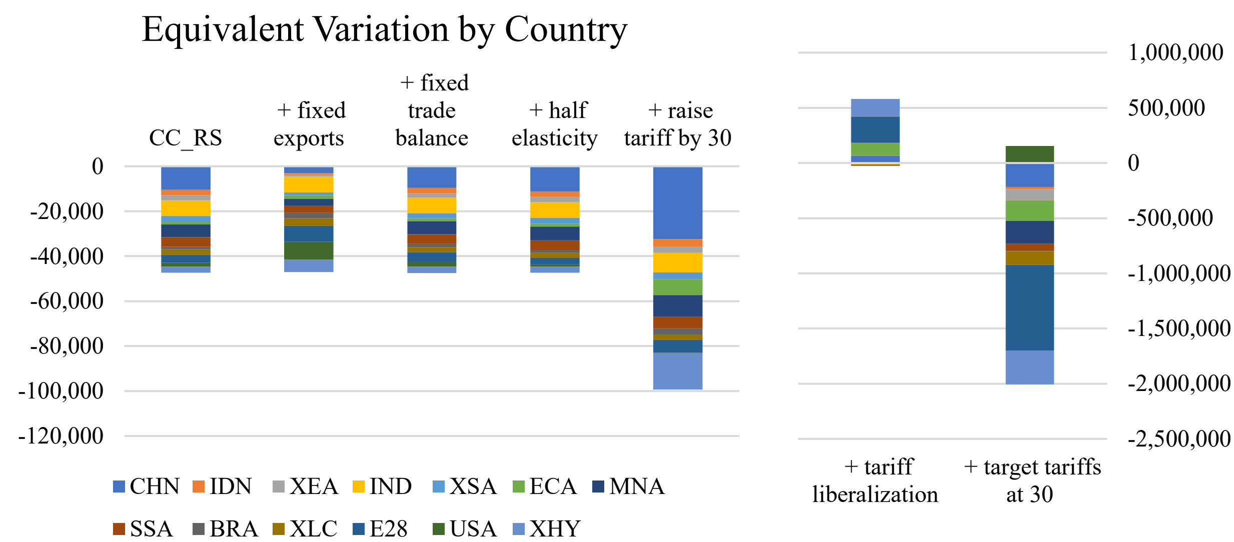

Figure 5. Equivalent variation by region (Million USD)
Source: Simulation results.

Table X. Equivalent Variation under Climate Change and fixed exports scenario

Country	Allocative efficiency	Endowment	Productivity	Terms of trade	Total
CHN	-1,342	-2	-8,036	6,328	-3,052
IDN	-235	-9	-2,425	2,075	-593
XEA	-178	-9	-1,967	1,148	-1,005
IND	-213	-1	-7,287	556	-6,945
XSA	-25	0	-1,832	564	-1,292
ECA	-126	-1	-917	-480	-1,524
MNA	-137	0	-2,592	-296	-3,025
SSA	-174	0	-3,076	-10	-3,260
BRA	-269	0	-1,619	-591	-2,479
XLC	-375	-3	-2,531	-289	-3,197
E28	-925	-3	-2,913	-3,276	-7,117
USA	-695	-1	-4,770	-2,602	-8,069
XHY	-474	-5	-1,969	-3,102	-5,549
Total	-5,168	-35	-41,932	27	-47,108

The scenarios that increase tariffs, by 30 raise or target, show the largest decrease in welfare at the global level. Raising the tariffs decreases allocative efficiency for all countries, and makes global allocative efficiency decrease ten times more than the Climate Change scenario while making all tariffs 30% decreases allocative efficiency in all countries even further and global level is more than 300 times the Climate Change scenario. For the US, however, the latter improves the terms of trade enough to show a positive welfare effect. Tables Y and Z show the decomposition of welfare by country and effect.

Table Y. Equivalent Variation under Climate Change and increased tariffs scenario

Country	Allocative efficiency	Endowment	Productivity	Terms of trade	Total
CHN	-17,963	-2	-8,024	-6,458	-32,447
IDN	-707	-8	-2,342	-102	-3,160
XEA	-1,834	-9	-1,932	852	-2,923
IND	-3,343	-1	-7,274	1,924	-8,693
XSA	-1,151	0	-1,782	-31	-2,964
ECA	-6,572	-1	-932	416	-7,090
MNA	-2,923	0	-2,546	-4,108	-9,578
SSA	-2,524	0	-3,037	329	-5,233
BRA	-2,112	0	-1,557	973	-2,696
XLC	-2,377	-3	-2,446	2,411	-2,414
E28	-5,064	-3	-2,979	2,273	-5,773
USA	-1,404	-1	-4,719	5,817	-307
XHY	-9,677	-5	-2,021	-4,323	-16,026
Total	-57,651	-35	-41,591	-27	-99,303

Table Z. Equivalent Variation under Climate Change and 30% tariffs scenario

Country	Allocative efficiency	Endowment	Productivity	Terms of trade	Total
CHN	-223,520	-2	-7,956	15,942	-215,536
IDN	-14,121	-8	-2,334	-5,403	-21,867
XEA	-64,696	-8	-1,925	-34,965	-101,594
IND	-22,797	-1	-6,762	29,206	-354
XSA	-3,826	0	-1,745	8,652	3,082
ECA	-123,411	-1	-950	-61,125	-185,487
MNA	-84,875	-1	-2,877	-118,106	-205,859
SSA	-35,157	0	-3,095	-27,148	-65,400
BRA	-12,147	0	-1,514	10,983	-2,678
XLC	-76,117	-3	-2,489	-44,767	-123,376
E28	-736,590	-3	-3,036	-37,061	-776,690
USA	-98,890	-1	-4,190	254,601	151,520
XHY	-293,873	-5	-1,904	-10,614	-306,396
Total	-1,790,019	**-34**	**-40,777**	-19,805	-1,850,635

Conclusions

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Appendix

Table A1. Country aggregation

No.	New Code	Region Description	Comprising old regions
1	XHY	Rest of high-income countries	aus nzl hkg jpn kor twn sgp can xna alb bgr blr isr
2	XEA	Rest of East Asia	xoc mng xea brn khm lao mys phl tha vnm xse
3	CHN	China, P.R.	chn

No.	New Code	Region Description	Comprising old regions
4	IDN	Indonesia	idn
5	XSA	Rest of South Asia	bgd npl pak lka xsa
6	IND	India	ind
7	USA	United States	usa
8	XLC	Rest of Latin America	mex arg bol chl col ecu pry per ury ven xsm cri gtm hnd nic pan slv xca dom jam pri tto xcb
9	BRA	Brazil	bra
10	E28	European Union (28)	aut bel cyp dnk est fin fra deu grc hun irl ita lva ltu lux mlt nld pol prt svk svn esp swe gbr che nor xef
11	ECA	Rest of EU and Central Asia	cze hrv rou rus ukr xee xer kaz kgz tjk xsu arm aze geo
12	MNA	Middle East and North Africa	bhr irn jor kwt omn qat sau tur are xws egy mar tun xnf
13	SSA	Sub-Saharan Africa	ben bfa cmr civ gha gin nga sen tgo xwf xcf xac eth ken mdg mwi mus moz rwa tza uga zmb zwe xec bwa nam zaf xsc xtw

Table A2. Sector aggregation

No.	New Code	sector Description	Comprising old sectors
1	pdr	Paddy rice	pdr
2	wht	Wheat	wht
3	gro	Other grains (includes maize)	gro
4	RAgr	Rest of Agriculture	v_f osd c_b pfb ocr ctl oap rmk wol frs fsh
5	Coal	Coal	coa
6	Oil	Oil	oil
7	Gas	Gas	gas gdt
8	En_Int_ind	Energy intensive industries	oxt chm bph rpp nmm i_s nfm
9	Food	Food	cmt omt vol mil pcr sgr ofd b_t
10	Oth_ind	Other industries	tex wap lea lum ppp fmp ele eeq ome mvh otn omf
11	Oil_pcts	Oil products	p_c
12	Electricity	Electricity	ely
13	otp	Other transport	otp
14	atp	Air transport	wtp
15	wtp	Water transport	atp
16	Oth_ser	Other services	wtr cns trd afs whs cmn ofi ins rsa obs ros osg edu hht dwe