Economic Damages, Country Inequality and the Cost of Emissions Reduction in a Large-Dimensional Global Trade and Climate Model

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Introduction: Dimension Matters!

- It is not unusual to find numerical simulations that are dimensionally very large – and often impossible to solve – especially in studies that detail environmental impacts and climate modelling or where optimization routines are required (the so-called 'curse of dimensionality').
- Standard climate change economic models are either very small dimensionally and/or are not forward-looking or intertemporal (Nordhaus, 1991, DICE/RICE model; Roson and Mensbrugghe, 2012, EVISAGE model; Tol, 2002, 2012)
- Model dimension matters: Averaging across countries and extremes in impacts distorts overall and country-specific damages; it misses the heterogeneity! Severe damages occur even though standard damage functions are very limited in scope and impact.

GTAP Data, GTAP-INT, GTAP-R, GTAP-IAM

- (139 country model, GTAP-INT): 57 commodity groups (with trade and spatial dimension), including paddy rice, wheat, cereal grains, vegetable, fruits and nuts, bovine cattle, sheep, goats, horses, sugar cane, milk, wool, forestry, fishing, coal, oil, gas, meat products, vegetable oils and fats, dairy products, textiles, beverages and tobacco, wood products, paper products, chemical, rubber, leather products, plastics, metal products, electronic equipment, machinery, manufactures, air transport, motor vehicles, electricity, construction, business services, defense, public administration, dwellings, communication, financial services, construction, transport, recreational and other services, etc.
- (30–60 region/country, GTAP-R; 30-60-139 region/country model, GTAP-IAM): Energy and power components in the GTAP-R, IAM/GTAP-EP model included: Coal, oil, gas, oil products, fossil fuel electricity, renewables, non-fossil electricity, etc.

GTAP INT

The Effects of Climate Change on Growth and GDP

- Using modified Roson and Satori (2016) climate change damage (+/-) functions, we solve a large dimensional intertemporal GTAP trade global model to account for the some of the effects of global warming (e.g., loss in agricultural and labour productivity, sea level rises impact on land area, and human health effects) for 139 countries, by decade and over the long term – where producers look forward and adjust price expectations and capital stocks to account for future climate effects. (Fires, floods infrastructure damage from sea level rise (except for AUS), tropical storms (except for USA) , pollution, etc. not yet included.)
- Results are generated in terms of losses in GDP for each country and by various RCPs/SSPs, with overall results for 1-4^{o}C (SSP2 'business as usual' baseline).

GTAP Model Database/Dimension

- Example: GTAP database v7: The full database includes 112 (extendable to 139) regions (countries) and 57 commodities.

Table: GTAP model with different database/aggregation levels.

ID	Model Size	Number of endogenous variables	Number of exogenous variables	Number of non-zeros
1	112 regions, 3 commodities, 47 periods	13939336	7850081	58681307
2	112 regions, 4 commodities, 47 periods	18592712	10450826	78830677
3	112 regions, 5 commodities, 47 periods	23319784	13083155	97089894
4	112 regions, 26 commodities, 47 periods	139612072	75657968	547479803
5	112 regions, 34 commodities, 47 periods	192462632	103159736	749419439
6	112 regions, 57 commodities, 47 periods*	505112836	260697767	$1.815*10^9$

Source: Authors' calculation. Note: * Number of non-zeros is an approximation.

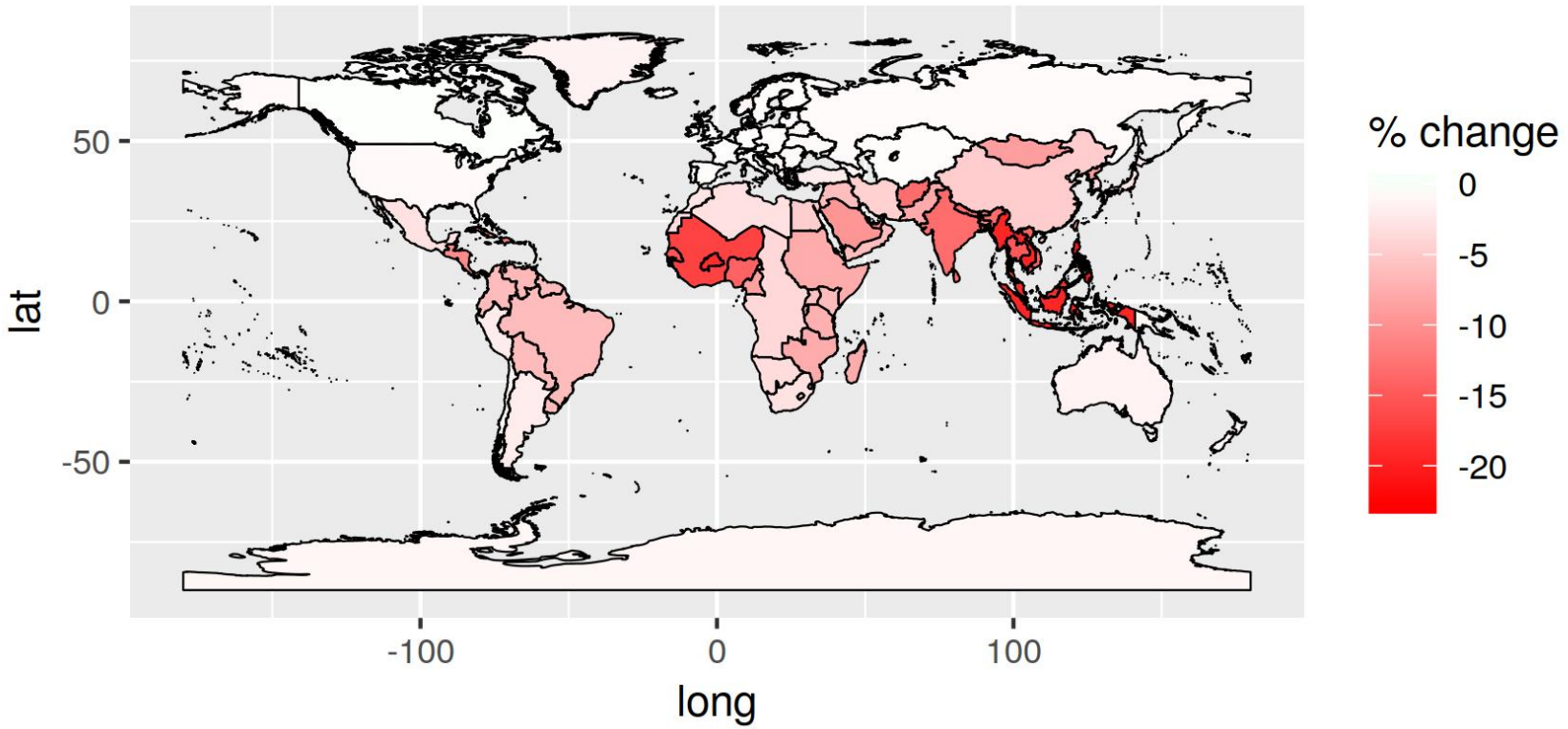
Top Ten 'Large and Small Effects' (140 country database with no tourism and energy demand shocks); 3^oC Path

Table: Dimension matters: Climate change impacts on world GDP in the long run: intertemporal vs first-order/recursive estimation (% change).

Countries/regions	GTAP-INT*	First order**	Countries/regions	GTAP-INT*	First order**
Ghana	-17.57	-13.19	Switzerland	-0.35	1.42
Cote dIvoire	-17.53	-13.03	Sweden	-0.35	1.72
Nigeria	-15.72	-13.93	Finland	-0.25	1.48
Rest of Western Africa	-15.57	-6.07	Ukraine	-0.24	0.92
Philippines	-14.80	-7.42	Belarus	-0.25	0.18
Indonesia	-13.27	-6.80	Canada	-0.22	1.27
Senegal	-13.00	-9.58	Rest of Europe	-0.21	0.01
India	-10.35	-6.24	Slovakia	- 0.47	1.23
Rest of Southeast Asia	-12.92	-9.83	USA	-0.62	-0.18

Source: * Authors' calculation. ** From Roson, R. and Sartori, M. (2016), 'Estimation of climate change damage functions for 140 regions in the GTAP 9 database', *Journal of Global Economic Analysis*, 1(2), 78–115.

Climate Change Impacts – Long Run; 4^oC Path, $\%\Delta$ GDP



Source: Authors' calculation.

Estimation of long term GDP loss per year in 2100 and forward under global warming scenarios ($US billion/year)

	4°C	3°C	2°C
World Total	**-23,149**	**-9,593**	**-5,659**
Sub-Saharan Africa	-8,073.68	-2,889.66	-1,927.78
India	-4,484.96	-2,070.06	-1,149.36
Southeast Asia	-4,158.88	-2,073.09	-1,166.23
China	-1,716.91	-701.75	-394.59
Latin America	-1,371.81	-576.65	-259.82
Rest of South Asia	-1,157.92	-469.98	-283.78
Middle East and North Africa	-1,032.27	-451.96	-241.12
United States of America	-697.77	-223.83	-168.48
Japan	-253.18	-54.43	-23.02
Australia	-117.42	-36.87	-23.72
South Korea	-81.44	-14.72	-7.86
Russian Federation	-24.49	-10.88	-6.53
United Kingdom	17.78	4.06	0.35
Germany	23.85	5.38	2.46
France	26.92	7.11	1.80
Vietnam	-247.09	-106.0	-63.58

Sources: Authors' calculation

Cumulative Losses in GDP from 2017-2100 (bill. USD)

	Impacts (GDP)		
	4°C	3°C	2°C
World Total	-604460.42	-271250.18	-171745.14
Sub-Saharan Africa	-177398.70	-67745.57	-49231.04
India	-131574.85	-65495.65	-39665.53
Southeast Asia	-118076.85	-62233.61	-37692.25
China	-64024.08	-28239.51	-16947.87
Latin America	-39444.52	-17240.66	-8529.39
Rest of South Asia	-29243.05	-11482.45	-8357.61
Middle East and North Africa	-25582.51	-12400.73	-7021.93
United States of America	-14401.80	-5699.37	-4334.33
Japan	-6625.19	-1716.01	-624.83
Mexico	-3133.90	-1289.18	-486.12
Australia	-2898.86	-1097.39	-695.97
Vietnam	-7418.66	-3369.44	-2234.69

Source: Authors' calculation.

What do these BIG Numbers Mean?

- Global long term economic damages in 2100 (albeit with limited damage functions) at 3^{o}C are \$US 9.5+ trillion per year and at 4^{o}C losses are \$US 23+ trillion per year.
- Long-run annual losses (on average) range from 2–6% depending on SSP and/or assumptions on economic growth.
- **The real point**: Some country losses are especially severe. GDP losses, for example, at 4^{o}C, for Cambodia, Sri Lanka, and Nicaragua are over 17%, for Indonesia 19%, for India 14%, Thailand 17%, Singapore 16%, the Philippines 20%, and for much of Africa the losses range from 18 to over 26% of GDP. Global losses in GDP during the Great Depression (1930s) were 15%. (China 4.6%, USA 0.9%)

GTAP IAM
(Intertemporal Finite Horizon)
GTAP-R
(Dynamic Adaptive Recursive)

GTAP Energy and Power model; Climate model

- GTAP–E: Burniaux and Truong (2002) include energy as a separate consumption bundle and production factor together with capital in their static version of the GTAP model.
- GTAP–P: Peters (2016a,b) further extends the GTAP-E model framework for a power and renewables component.
- We follow Glotter (2014) and assume 3-reservoir carbon cycle model.
- We also follow the MERGE model (Manne et al., 1995) and assume a simple one layer cycle model for other GHG concentrations; and IPCC (1997) and Manne et al., (1995), by assuming that the concentration of CO_2, CH_4 and N_2O are the main causes of radiative forcing.

Comparing GTAP-IAM (SSP2) Model Results Compared to Steady-State GTAP-INT Results, % loss in Annual GDP

Table: Long run impact: Heavily impacted countries and AUS (%/GDP)

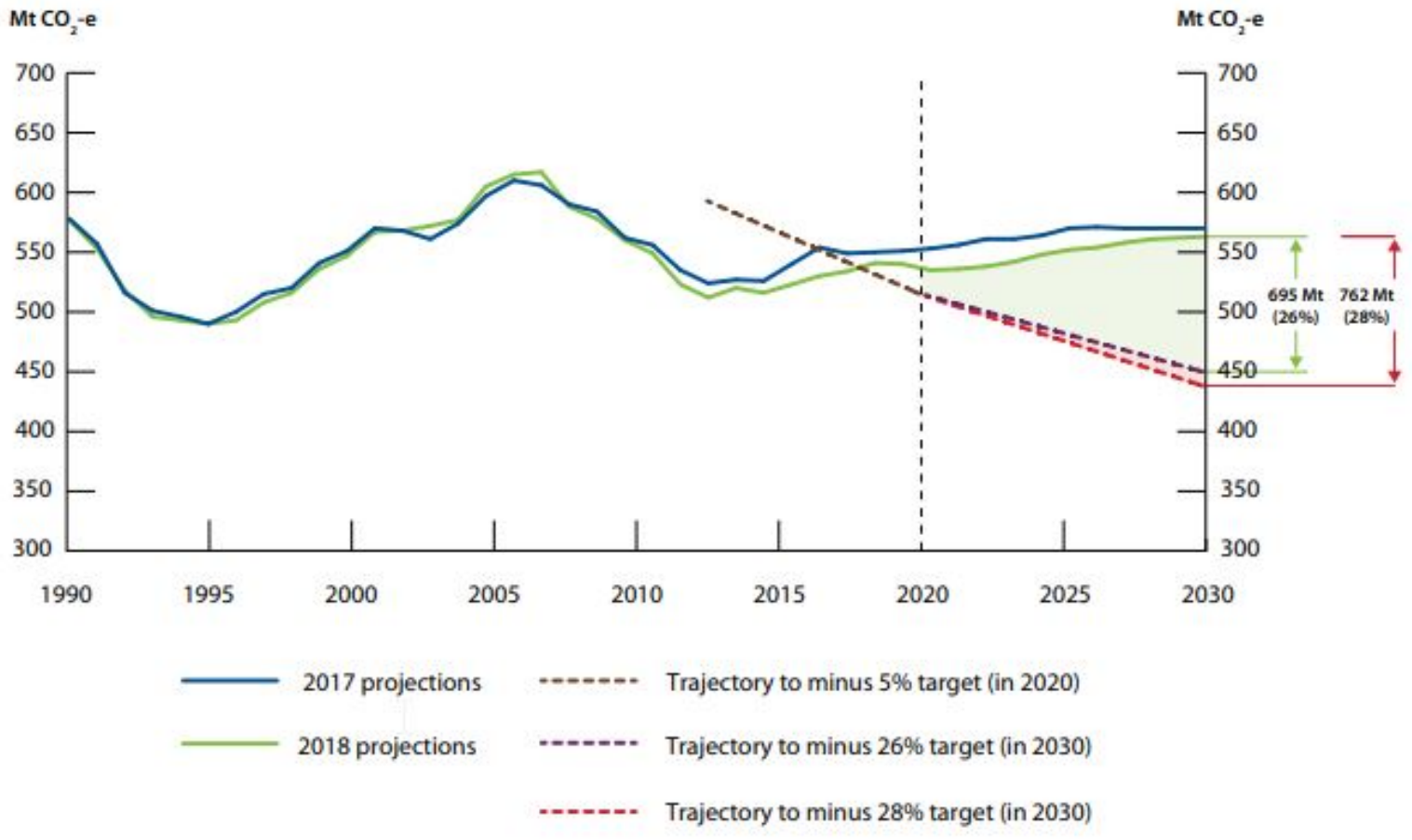
	GTAP IAM SSP5/RCP8.5	Local temperature	GTAP INT 4^oC
Rest of Southeast Asia	-28.38	-22.38	-18.57
Laos	-25.37	-21.75	-15.76
Rest of Western Africa	-25.31	-23.35	-21.94
Cambodia	-24.42	-19.25	-17.18
Burkina Faso	-24.35	-23.11	-23.59
Rest of South Asia	-24.17	-23.28	-13.88
Togo	-22.16	-21.11	-26.56
Philippines	-21.54	-14.37	-20.99
Rest of Central America	-21.44	-15.82	-18.23
Cote dIvoire	-20.26	-18.35	-25.25
Australia	-1.78	-1.70	-1.58

Emissions Reduction and Avoided Damages for Australia: GTAP-R

Costs of Emissions Reduction in Australia?

Overall change since the 2017 projections

Figure 4 Australia's emissions trends, 1990 to 2030



Damages or Avoided Costs (BAU)

- Included: Losses in agricultural productivity, losses in labour productivity, limited human health effects, sea level rise (inundation effect), sea level rise: Infrastructure damages, limited biodiversity losses.
- Not counted: Damages to major environmental assets, bush fires (and some floods), more intense tropical storms. etc. The cost of damages to environmental assets, a large portion of fire and flood events, the effects of pollution and losses in biodiversity are not captured.
- (2020-2050 BAU/RCP 8.5) Infrastructure damages $611 billion; productivity losses (agric and labour) $151 billion; biodiversity losses (WTP): $246 billion.
- **Total: $815 billion USD ($1.19 trillion AUD).**

Costs of Emissions Reduction

- Included: The cost of transition from fossil fuels to renewables (energy, transport, etc.), changes in net exports, deadweight losses from a price on carbon (or equivalent renewable target), cost of land-use changes, cost of negative emissions technology (NET).
- Key drivers: Rapidly falling price of renewables, changes in resource efficiency.
- **Example Target: 70% share of renewables in end-use energy consumption in 2050. (ROW on Paris target.)**
- (2020-2050 target): Deadweight loss/change in GDP ($31.65 billion); cost of energy transition and NET ($40.76 billion). Total is $72.41 billion USD ($106.81 billion AUD).
- **Or: $106 billion; or .25% of cumulative GDP**

Thank you!

- Thanks for listening!
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