Marshall Burke:
Climate Change and Economic Growth

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XXVI Annual Conference of the Central Bank of Chile

“Implications of Climate Change and Ecosystem Services Degradation for Macroeconomic and Financial Stability”

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1. This paper

- **This paper**
  - Burke et al. (2015, 2023, this presentation) develop a new model to better understand and quantify the GDP effects of climate change (CC)
  - This is key for assessing losses and damages, their distribution, possible compensation, and other economic effects (including welfare losses)
  - Also key for assessing costs and benefits of CC mitigation and adaptation
- **Main paper contributions**
  - Addresses inconsistencies between micro and macro results; quantifies the impact of temperature on GDP, accounting for highly non-linear responses to temperature and generalizes for diff. sectors, periods, and rich/poor countries
- **Main results**
  - Economic productivity is non-linear in temperature – peaking at 13º C and declining strongly at higher temperatures
  - CC will reduce average global income by roughly 23% by 2100 (Burke, 2015)
  - 1 ton of CO_2 emitted in 1990 causes \$4 in global cumulative discounted damages by 2020 and an additional \$327 in discounted damages through 2100 (at a 2% discount rate).

2. GEC: lack of science and economic estimates

- **Scenarios of climate change (IPCC) reflect:**
  - large dispersion
  - time trend in upward revision of probs. assoc. to more catastrophic scenarios
  - strong presence of non-linearities and catastrophic trigger points
- **More worrisome:**
  - There are few scientific models and – to the best of my knowledge – no estimates of the economic effects of the interactions between the 5 direct drivers (IPBES) of the anthropogenic Global Environmental Catastrophe (GEC)
  - For example:
  - No scientific models of the interaction between global warming – wildfires – desertification – more land use – more global warming
  - No estimates of econ. effects and socio-economic feedback to environment

3. GDP effects beyond this paper: highly sensitive to model specifications

a) **Dependent variable**
- ➢ Micro-foundations relate temperature to output level (Dell et al., 2012); sector-consistent macro models for GDP growth (Burke et al.)
- ➢ Growth (level) effects (do not) compound over time: predictions of future losses vary enormously (Newell et al., 2021)

b) **Temperature functional form**
- ➢ Linear effect (Dell et al., 2014) or higher-ordered polynomials (Burke et al., 2018)
- ➢ This affects the magnitude of damage estimates (Newell et al., 2021)

c) **Controls for unobserved trends**
- ➢ FE control for trends, but they do not admit country-specific trends: robust to OV bias, but they may also absorb variation necessary to identify relationships (Deschenes and Greenstone, 2012)
- ➢ Parametric trends (included in Burke et al., 2018) allow for country-level heterogeneity, but constrain the functional form of country trends. This could result in over-fitting.

3. GDP effects beyond this paper: highly sensitive to model specifications

Model Specifications						
Paper	**Dep. Variable**	**Temperature Functional form**	**Country FEs**	**Year FEs**	**Region X Year FEs**	**Time Trend Polynomial**
Hsiang (2010)	Levels	Piecewise linear	✓	✓	✓	2
Dell et al. (2012)	Growth	Linear	✓	✓	✓	-
Deryugina and Hsiang (2014)	Levels	Piecewise linear	✓	✓	X	-
Hsiang and Jina (2014)	Growth	-	✓	✓	X	2
Burke et al. (2015)	Growth	Quadratic	✓	✓	X	3
Burke et al. (2018)	Growth	Quadratic	✓	✓	X	3

3. Literature results: 2100 GDP level effects are (not) credible if based on growth (level) models

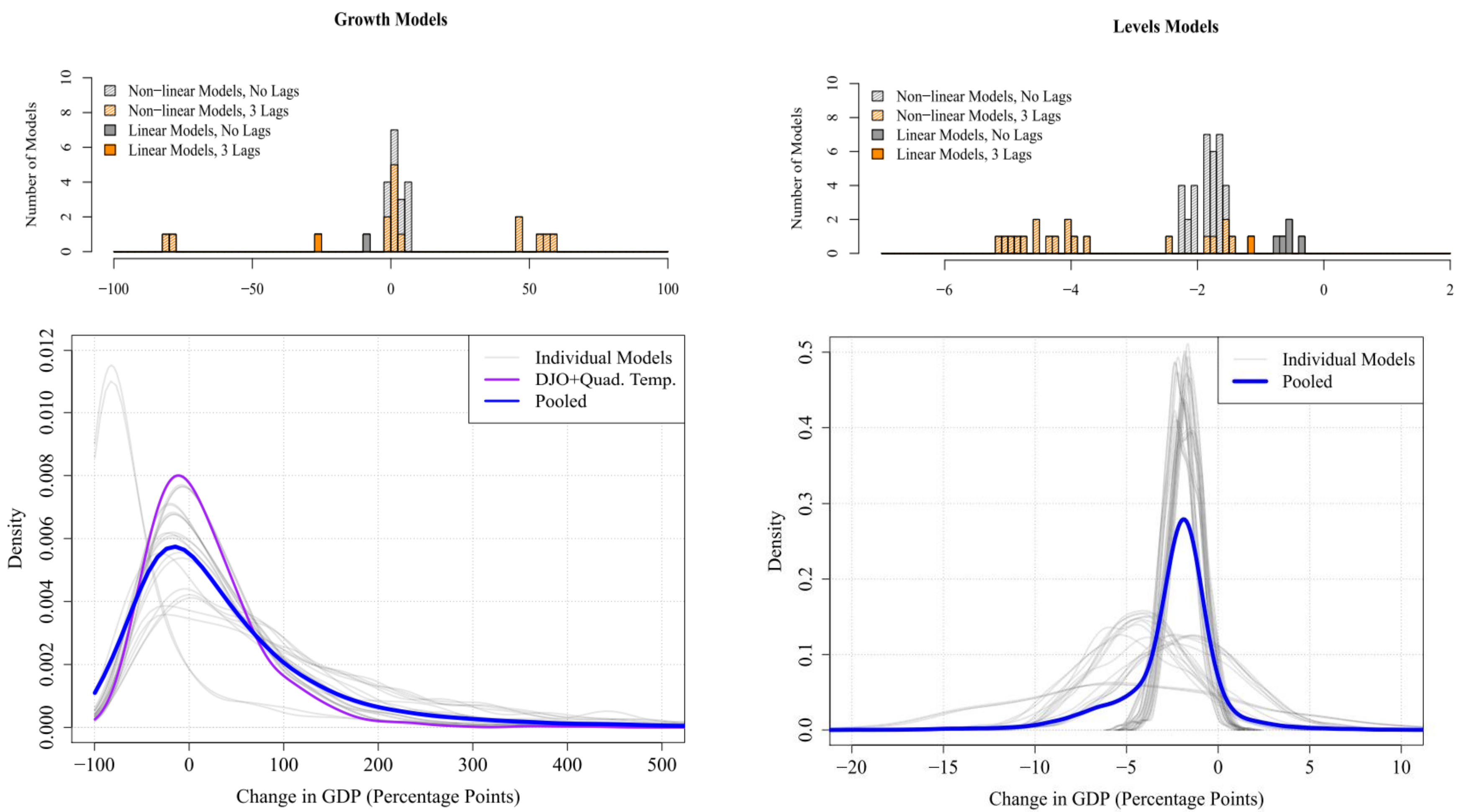
Estimated percentage effects of unmitigated global warming on GDP level by 2100

	Temperature Functional Form			
	Linear	Quadratic	Cubic	Spline
A. GDP Growth Models				
Year FEs, No time trend	-1.0	-13.3	-16.4	-7.8
Year FEs, 1 degree time trend	-35.3	-46.5	-38.4	-37.1
Year FEs, 2 degree time trend	-37.2	**-49.4 (1)**	-49.6	-49.5
Year FEs, 3 degree time trend	-42.5	-54.3	-54.7	-55.9
Region X Year FEs, No time trend	22.3	5.6	3.6	32.6
Region X Year FEs, 1 degree time trend	-21.5	-32.9	-19.5	-21.0
Region X Year FEs, 2 degree time trend	2.3	-17.4	-6.3	-6.1
Region X Year FEs, 3 degree time trend	-6.2	-27.3	-19.2	-22.2
B. GDP Level Models				
Year FEs, No time trend	-0.4	-1.7	-1.6	-2.2
Year FEs, 1 degree time trend	-0.4	-1.8	-1.7	-2.2
Year FEs, 2 degree time trend	-0.6	-2.0	-1.8	-2.3
Year FEs, 3 degree time trend	-0.8	-2.1	-2.0	-2.5
Region X Year FEs, No time trend	-0.6	-1.8	-1.8	-2.2
Region X Year FEs, 1 degree time trend	-0.7	-1.9	-1.8	-2.2
Region X Year FEs, 2 degree time trend	-0.5	-1.8	-1.7	-2.0
Region X Year FEs, 3 degree time trend	-0.5	-1.8	-1.7	-2.1

Note: This results is comparable to Burke et al.'s 23% result.

Source: Newell et al. (2021).

3. Literature results: 2100 GDP level effects are (not) credible if based on growth (level) models



Source: Newell et al. (2021)

4. Welfare effects beyond GDP: complexity and interactions

- **The mechanisms through which climate may affect GDP are many, are complex, and hard to analyze comprehensively** (Dell et al., 2014)
  - Even if we know each mechanism, we don't know how these mechanisms interact (Nordhaus and Boyer, 2000; Tol, 2002).
- Economic aggregates are **not direct welfare measures**, and do not reflect non-market values affected by climate change (Newell et al., 2021)
- The **complexity of the climate-economy relationship is apparent** in:
  - Agriculture (Mendelsohn et al. 2001; Deschenes and Greenstone, 2007), ocean fisheries, fresh-water access, storm frequency, migration, tourism (IPCC, 2022); mortality (Deschenes and Moretti 2007), crime (Jacob et al. 2007), and drought on conflict (Miguel et al. 2004).

5. Loss and damage compensation. Is it feasible? Many questions to address

a) **Selecting a discount rate**
   - As shown by Burke, estimates of Social Cost of Carbon (SCC) are highly sensitive to the discount rate (i.e., 4 to 8 times of differences in SCC when we compare a 3% rate with the Ramsey discount rate)
   - Ramsey-Koopmans discount rate:

$$r_t = \delta + \rho g$$

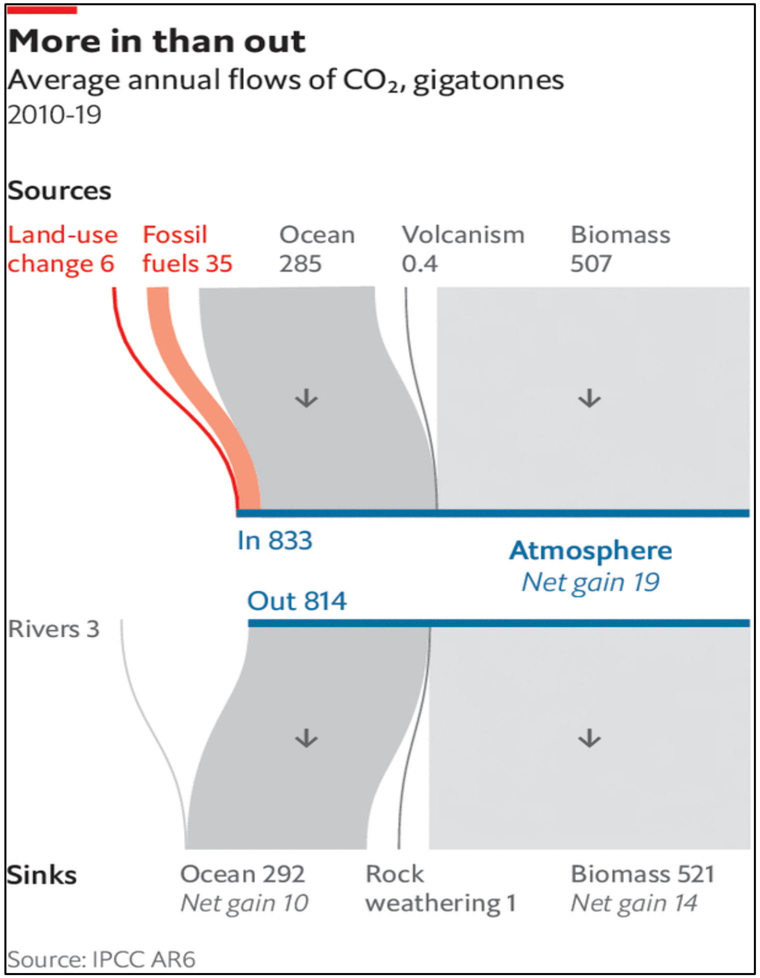
     where r is the consumption annual rate of discount, g is the long-run growth rate, δ is the pure annual rate of time preference, ρ is the utility-function-curvature parameter (Edwards, 2008; Edwards, 2016)
   - Large dispersion of parameter vales; all parameters endogenous to CC?

b) **When should we start to calculate loss and damage?**
   - It's not clear when to begin counting emissions that parties should be held accountable for

c) **Consumption or production-based emissions**
   - Should we be held responsible for emissions associated with production or consumption?

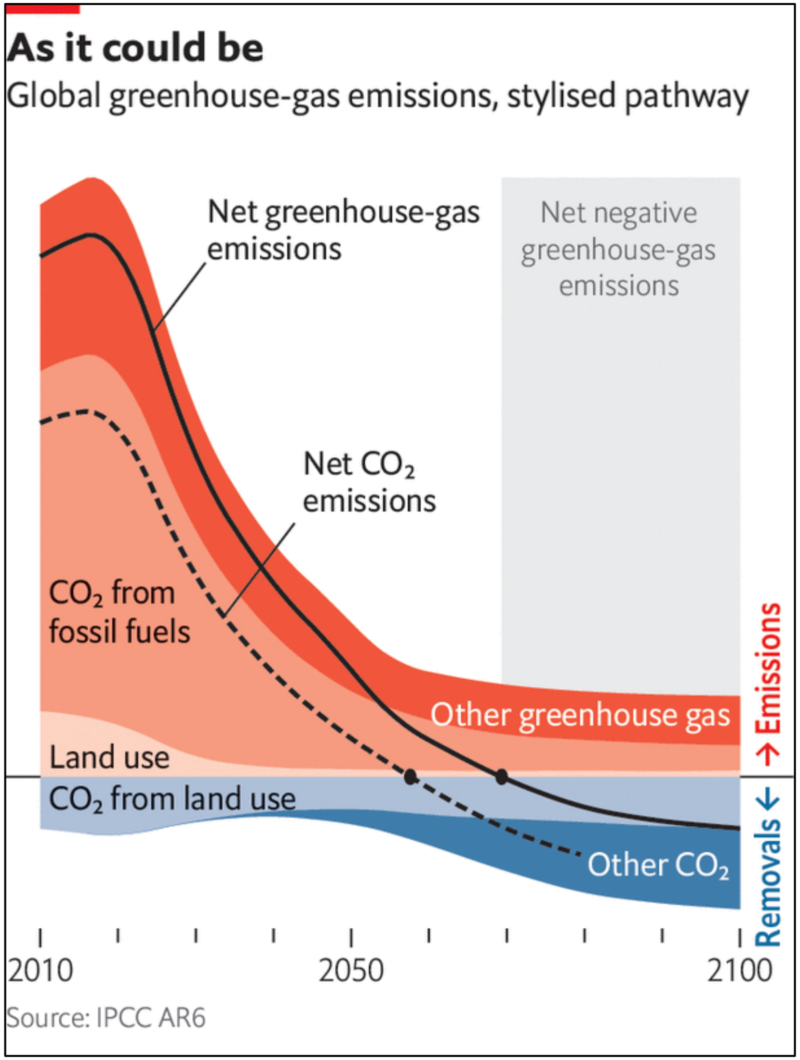
6. Implications:
A. Firm science: accounting for CO_2 flows and stocks

- Stock:
  - 1 trillion tons of CO2 have accumulated thanks to humans
- Flows per year (now):
  - Human-caused gross flows into atmosphere: 41 billion tonnes
  - Total earth's net flows into atmosphere: 19 billion tonnes
  - Seems small? No. It's terribly large and totally unsustainable



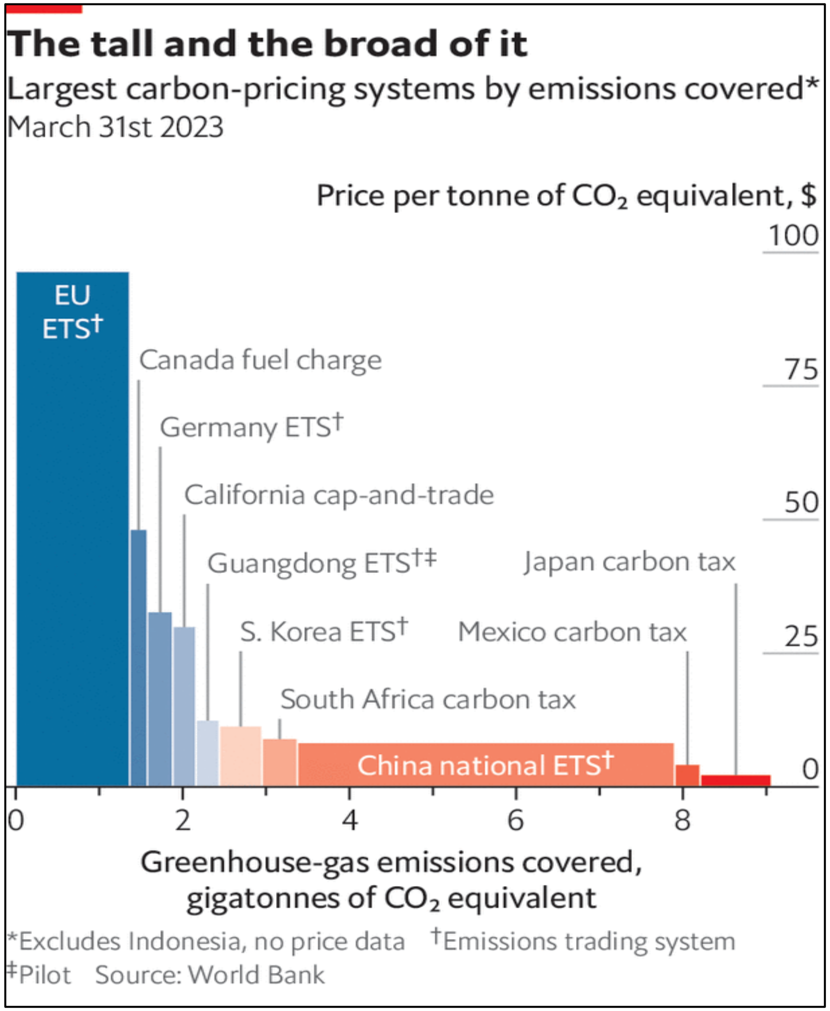
6. Implications:
B. Science and shaky commitments toward Net Zero

- IPCC AR6 scenario assumes commitments to achieve net zero by 2050-2070 are enforced
- Highly unlikely given current trends:
  - Every year the peak of CO2 emissions is pushed a few years forward
  - Carbon-dioxid removal (CDR) is still an infant technology and an embrion industry
  - It's politics, stupid!



6. Implications:
c. Market-based solutions

- Among market-based solutions, carbon pricing offers great potential
- Today's largest carbon-pricing systems (in large countries) reflect huge dispersion in carbon prices per ton of CO2eq: From a few cents in Japan to US$ 90 in the EU's ETS
- U.S.: Trump forced EPA to reduce its social cost of carbon to US$ 5. Today it stands at US$ 51, still short of EPA's socially optimal level of US$ 190.



Conclusions

- Burke et al. (2015, 2023, this presentation) have developed an impressive research agenda, based on estimating micro-macro relationships between global warming and GDP losses that show very large aggregate effects of CC by 2100 – much larger tan previous research based on simple macro models and no non-linear effects
- Yet both science and economics are still far from modelling and estimating the true dimension of the Global Environmental Catastrophe: the strong interactions between the five direct drivers of GEC and their implications for economic aggregate variables (GDP, welfare) and their distribution, and their implications for other social variables (poverty, migration, crime, wars, health, institutions, democracy, ….)
- Every imaginable social, political, and economic variable will be deeply disturbed by GEC.
- Good domestic and international politics is the only way to avoid the most severe consequences of GEC.
- That requieres hard work now!

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