Introduction to the Economics of Development

10. How will climate change interact with the development challenge?

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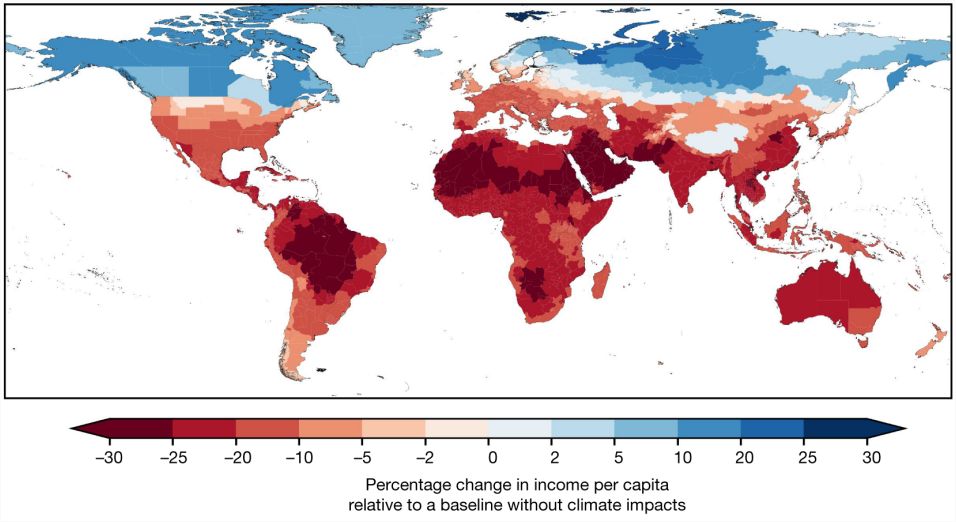
The plan

- Some facts: The distributional impact of climate change.
- Jedwab et al. (2023) "Lakes and Economic Development: Evidence from the Permanent Shrinking of Lake Chad"
  - Empirics: Difference in Differences
  - Theory: Quantitative Spatial Economics in Action
- Gollin et al. (2024) and the development-climate trade-off?

Another important issue

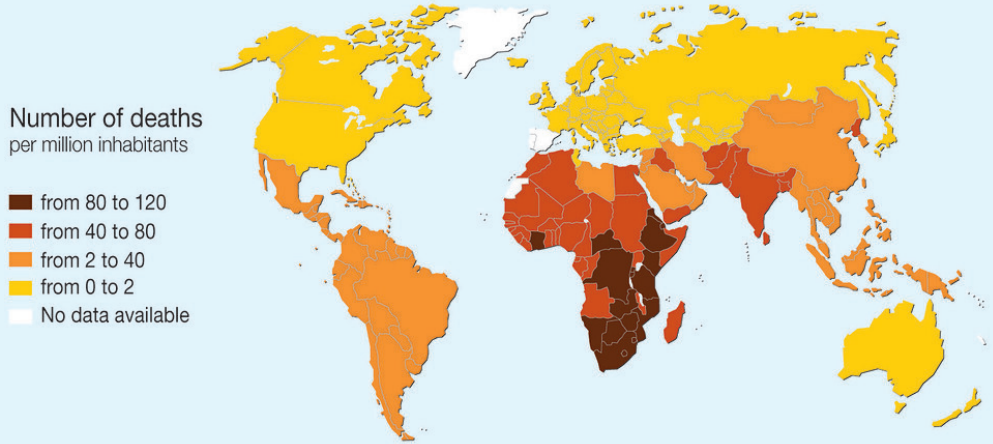
Projected impact of climate change by 2050



Kotz, Anders, Leonie 2024.

Climate change mortality

Estimated human mortality linked to climate change in 2000



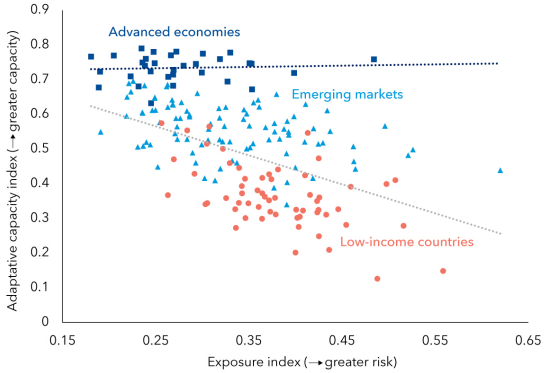
Source: ECLAC, *Climate Change and development in Latin America and the Caribbean. Overview 2009*, on the basis of WHO, *Climate Change and Human Health. Risks and Responses. Summary*, 2003.

Adaptability and Risk

Unequal costs of climate change

Poorer countries face greater risks from climate change and are less able to adapt to them.

(adaptive capacity and exposure indexes, points out of 1)



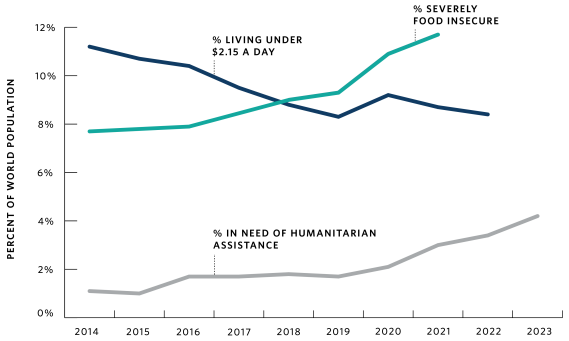
Source: IMF staff calculations based on 2015–18 data from the European Commission, the United Nations University Institute for Environment and Human Security, the University of Notre Dame, and the April 2020 World Economic Outlook.
Note: Dotted lines show estimated linear relationships for advanced economies, and for emerging market and low-income countries combined, respectively.

IMF

The changing development challenge

FIGURE 3

The Changing Nature of the Development Challenge

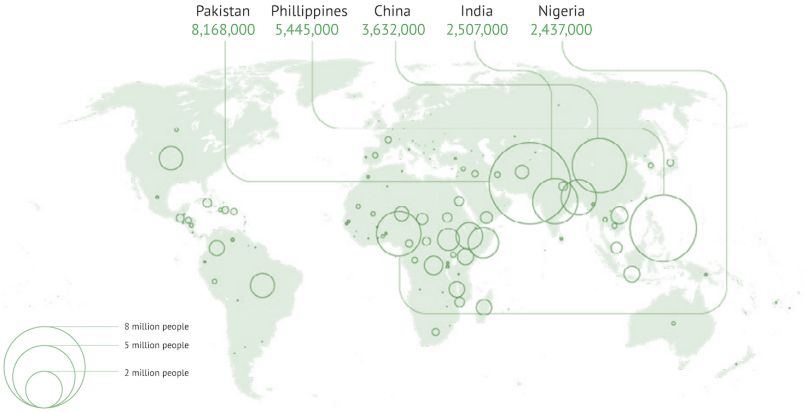


SOURCE: Author's calculations based on Nishant Yonzan, Daniel Gerszon Mahler, and Christoph Lakner, "Global Poverty in the 2020s Is on a New, Worse Course," World Bank Data Blog, October 14, 2022, https://blogs.worldbank.org/opendata/global-poverty-2020s-new-worse-course; UN Food and Agriculture Organization, International Fund for Agricultural Development, UN Children's Fund, UN World Food Programme, and World Health Organization, The State of Food Security and Nutrition in the World 2022: Repurposing Food and Agricultural Policies to Make Healthy Diets More Affordable (Rome: FAO, 2022), https://doi.org/10.4060/cc0639en; and UN Office for the Coordination of Humanitarian Affairs, "Global Humanitarian Overview 2023," December 1, 2022, https://www.unocha.org/2023gho.

Source

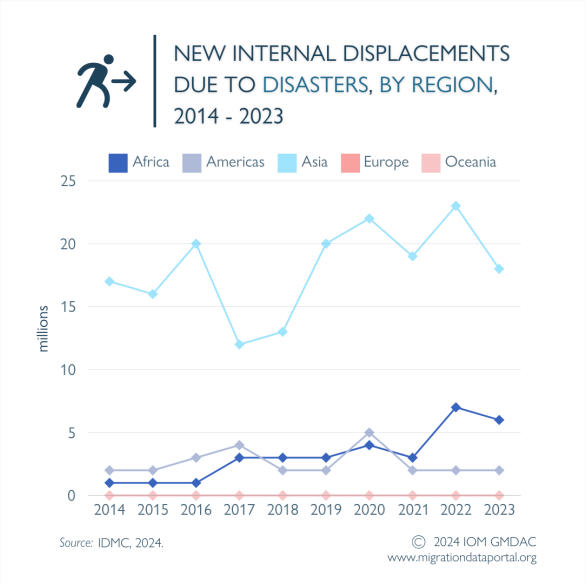
Displaced people

Number of internal displacements – forced movements of people within the borders of their country – recorded **during 2022** due to weather-related disasters

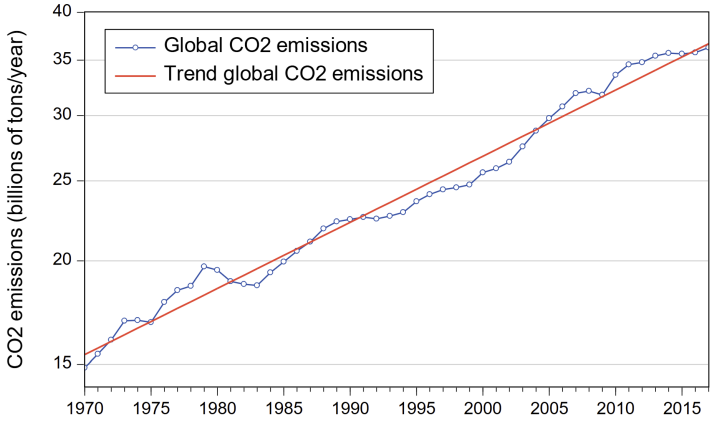


Source

Displaced people



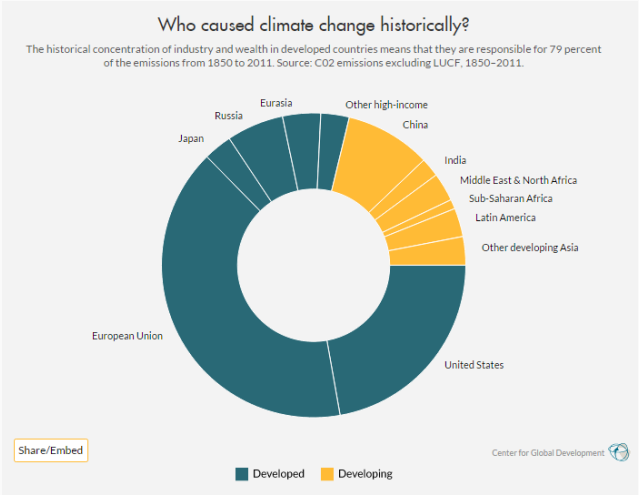
Things aren't really slowing down



Annual growth CO2: 1.8% per year
Annual growth CO2/GDP: - 1.5% per year

Nordhaus 2018

Who caused climate change



Center for Global Development

The triple whammy

1. LMIC did not cause climate change.

2. LMIC are most exposed to climate change.

3. LMIC are least able to mitigate climate change.

What we will discuss in these slides

- We won't discuss: How to solve climate change.
  - Some very interesting economics: Free riders, collective action, coalition building, political economy questions at a global scale.

- We will discuss: Estimating and understanding the past and future effects of climate change in a developing context.

Jedwab et al. 2023

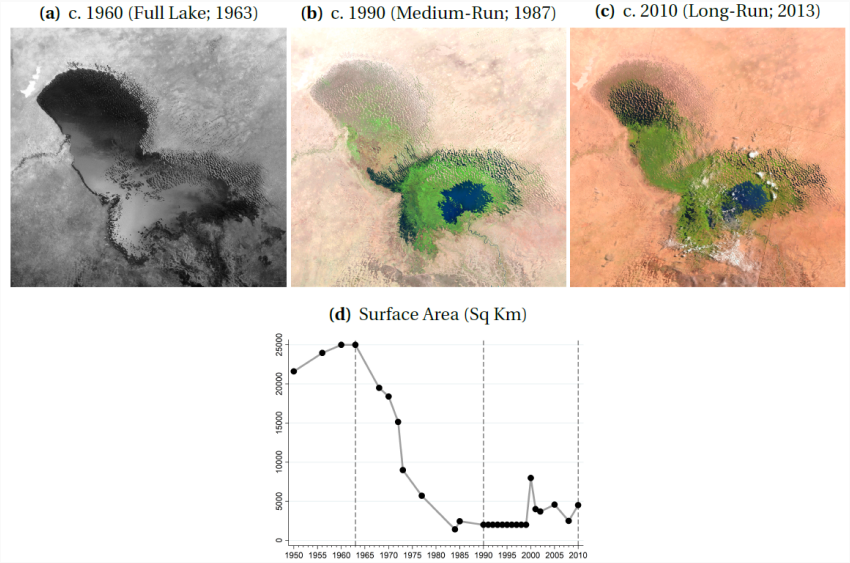
Jedwab et al. 2023 — Motivation

- 35% of the world's population live within 75km of a coastline.
- 35% of the world's population also live within 75km of a lake.
- Lakes are a significant productive asset in primary sector-oriented developing economies.
- Half of the world's lakes are shrinking.
- Lake shrinking reduces water supply but increases land supply — effects are potentially ambiguous.

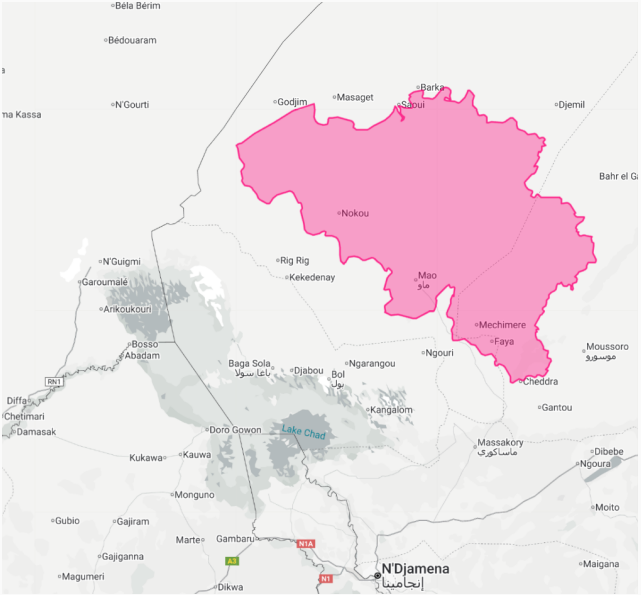
Jedwab et al. 2023 — Setting: Lake Chad.

- Lake Chad lost over 90% of its surface area water from 1963 to 1990.
- It *was* the 4th largest lake in Africa.
- The lake shrank due to a decrease in rainfall in the Central African Republic some 800km away.
- Widely accepting that this is a pretty directly caused by climate change.

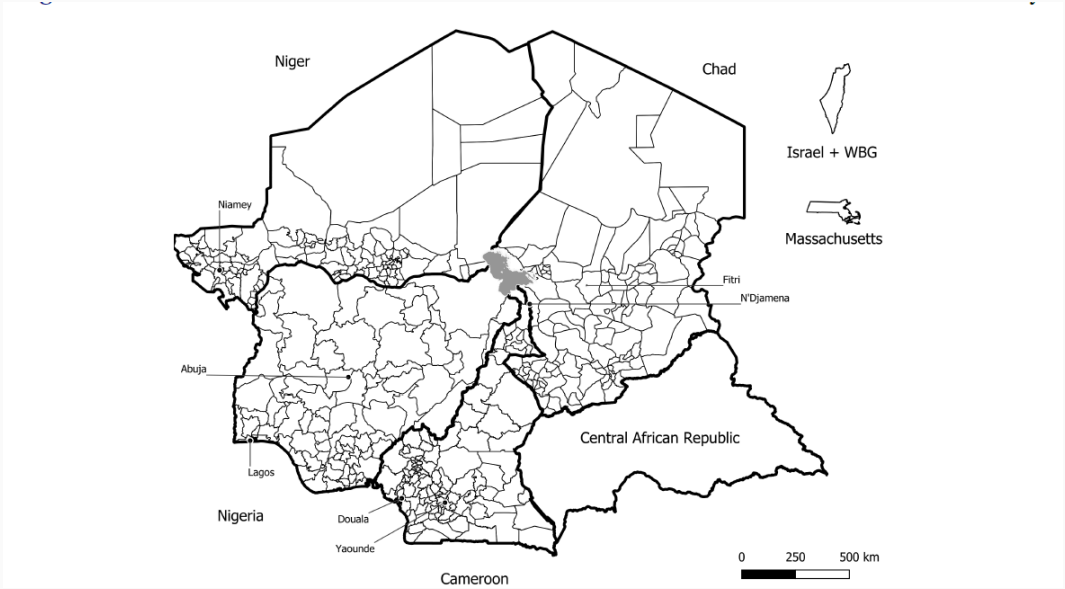
The shrinking of lake Chad



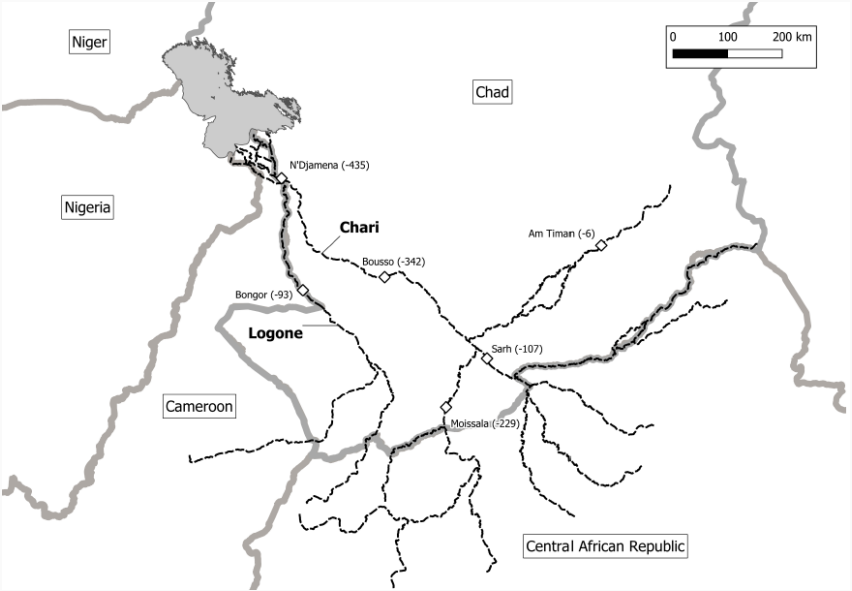
Belgium for scale



The location of lake Chad



Lake Chads feeder rivers



What is the impact of a shrinking lake Chad

- Less lake!
  - Cannot use the lake for transport.
  - Cannot use the lake to fish.
  - Cannot use the lake as a source of (fresh) water.
- Less local rain. 90% of rainfall comes from evaporation. Lake Chad is endorheic meaning it loses most of its water through evaporation.
- Local climate is warmer. Large lakes act as a heat sink, cooling the local climate in warm countries.
- More land. Relatively fertile land becomes available.
- Internal migration to/from the ex-lake.

Data

- Need data from before, during, and after the shrinking which started in 1963.
  - We will want to compare more vs less affected areas — so need a relatively small spatial unit.

- Hard to come by, especially in this setting.

- Focus on subdistrict population data in Niger (119), Cameroon (113), Chad (138), and Nigeria (93).

Empirical specification

$$\ln(TotPop_{st}) = \alpha + \beta_t ProxLake_s + \lambda_s + \theta_t + X_s B_t + \varepsilon_{st}$$

- s denotes subdistrict, t denotes year.
- λ_s are subdistrict fixed effects.
- θ_t are year fixed effects.
- $X_s B_t$ are time-invariant local controls X_s interacted with year fixed effetcs.

Threats to identification

$$\ln(TotPop_{st}) = \alpha + \beta_t ProxLake_s + \lambda_s + \theta_t + X_s B_t + \varepsilon_{st}$$

- What we want: β_t identifies the causal impact of being close to Lake Chad in year t (relative to some baseline year).
- What threatens this interpretation?

Threats to identification

$$\ln(TotPop_{st}) = \alpha + \beta_t ProxLake_s + \lambda_s + \theta_t + X_s B_t + \varepsilon_{st}$$

- What we want: β_t identifies the causal impact of being close to Lake Chad in year t (relative to some baseline year).
- What threatens this interpretation?
- In general: Anything that might change coincidentally and impact areas closer to Lake Chad differently from those further away.
- Feeder rivers drying up, less rain in areas close to the Central African Republic.
- Reverse causality: Population change could impact Lake Chad.
- Anything else that means treated and control areas could be on different trajectories.

Threats to identification

- Feeder rivers drying up, less rain in areas close to the Central African Republic.
  - Control for distance to the rivers.
  - Control for distance to the Central African Republic.

- Reverse causality: Population change could impact Lake Chad.
  - Turn to science.
  - Almost all of Lake Chad's inflow comes from CAR.
  - Almost all of Lake Chad's outflow is due to evaporation.

- Anything else that means treated and control areas could be on different trajectories.
  - This is a little harder...

Difference in differences analysis

$$\ln(TotPop_{st}) = \alpha + \beta_t ProxLake_s + \lambda_s + \theta_t + X_s B_t + \varepsilon_{st}$$

- This empirical strategy is an example of what's called "difference-in-differences" analysis.
- The idea: Compare treated and control units (1st differences) before and after treatment (second differences).
- The assumption: Treated units would have evolved similarly to control units in the absence of treatment.
  - Parallel trends assumption.
- Here: In the absence of rainfall decreasing in CAR areas close and far from Lake Chad would have evolved similarly.
  - Once we control for distance to feeder rivers etc.
- We use the re-scaled control group post-treatment as a counterfactual for the treated group.
- Some intuition on the blackboard

Difference in Differences analysis

Animation

Why is this a DiD?

$$\ln(TotPop_{st}) = \alpha + \beta_t ProxLake_s + \lambda_s + \theta_t + X_s B_t + \varepsilon_{st}$$

- λ_s fixed effects control for all time-invariant differences between sub-districts.
  - As treatment (*ProxLake*) is defined at the subdistrict level this also controls for treatment and control average differences.

- θ_t fixed effects control for all location-invariant differences across time.
  - This controls for aggregate yearly trends.

Validating the parallel trends assumption

- This is the same problem we had before: Anything else that means treated and control areas could be on different trajectories.
- Can never be formally tested.
- However, we can provide indicative evidence in two ways.
  - Argue discursively that it's reasonable.
  - Look at parallel pre-trends.
- Parallel pre-trends: If treatment and control units are on a similar trajectory *before* treatment, this is evidence to suggest that they would have remained so in the absence of treatment.

Results — Temperature and rainfall

Table 4: Reduced-Form Effects, Local Climate, Flexible Specification

Benchmark = 1950-1964	(1) Niger	(2) Cameroon	(3) Nigeria	(4) Chad
Dependent Variable:	Mean Monthly Temperature (Celsius) in the Subdistrict in Period t			
0-150 Km*(1980-1994)	0.38***	0.89***	0.19***	0.19**
	[0.06]	[0.15]	[0.06]	[0.08]
150-300 Km*(1980-1994)	0.16***	0.31**	0.35***	0.06
	[0.06]	[0.15]	[0.07]	[0.07]
300-450 Km*(1980-1994)	-0.22***	0.02	0.10†	0.05
	[0.05]	[0.15]	[0.06]	[0.06]
Dependent Variable:	Log Mean Annual Rainfall (mm) in the Subdistrict in Period t			
0-150 Km*(1980-1994)	-0.08***	-0.26***	-0.13***	-0.25***
	[0.02]	[0.03]	[0.02]	[0.04]
150-300 Km*(1980-1994)	-0.04	-0.05*	-0.18***	-0.20**
	[0.03]	[0.03]	[0.02]	[0.04]
300-450 Km*(1980-1994)	-0.06***	-0.05**	-0.10*	-0.04*
	[0.02]	[0.02]	[0.05]	[0.02]
Subdistrict FE, Period FE	Y	Y	Y	Y
District Trends, Controls	Y	Y	Y	Y

Results — Violence

	(1)-(3): Non-Organized Violence		
Type:	All	Protests	Riots
Dependent Variable:		Number of Conflict Events	
Lake 0-150 Km	2.26**	1.76†	2.19***
	(1.12)	(1.34)	(0.80)
Lake 150-300 Km	1.44**	1.75**	1.02**
	(0.65)	(0.88)	(0.43)
Lake 300-450 Km	0.36	0.57	0.14
	(0.48)	(0.64)	(0.32)
Mean	13.69	9.25	4.45
# Non-Zeros	170	139	146
Country FE, Controls	Y	Y	Y

Table 1: Reduced-Form Effects, Total Population, 1950s-2010s

Dependent Variable:		Log Subdistrict Population in Year t			
(Relative to the c. 1963 Omitted Year)		Niger	Cameroon	Chad	Nigeria
Short-Term:	Proximity to Lake (log)*c.1970	-0.23**	-0.19**	_	_
		[0.09]	[0.08]	_	_
Medium-Term:	Proximity to Lake (log)*c.1990	-0.41***	-0.40***	-0.54***	-0.47***
		[0.11]	[0.14]	[0.08]	[0.16]
Long-Term:	Proximity to Lake (log)*c.2010	-0.33*	-0.36**	-0.62***	-0.37*
		[0.19]	[0.16]	[0.17]	[0.19]
Subdistrict Fixed Effects, Year Fixed Effects		Y	Y	Y	Y
District-Specific Linear Trends, Controls		Y	Y	Y	Y

A remaining threat to identification

- Our "treatment" is log distance to the lake.
- Implicitly this means we compare the outcomes of locations closer to the lake with those further away.
- This causes a fundamental issue.
  - Using as a comparison relatively closer locations increases the likelihood that the lake drying up affected the control locations too.
  - Using as a comparison relatively further away locations decreases the comparability of treatment and control, and throws increasing doubt on the suitability of control as a counterfactual for treatment.
- In the extremes:
  - If treatment is within 1km and control is between 1km and 2km it is likely that both will be similarly affected.
  - If treatment is within 10km and control is some places in Belgium.... it's unlikely that control locations are a good counterfactual for treated ones.
- This will always be an issue, to overcome it we have to understand better what spillovers look like — we need a model.

The model

- Jedwab et al. (2023) develop a quantitative spatial economics model.
- Here we will focus on the key intuition and ingredients rather than the model itself.
- Why do we want/ need a model?
  - As discussed: Everywhere is treated so to work out the overall effect we need a model.
  - Want to consider welfare.
  - Want to analyse the impact of policies on aggregate and distributional outcomes.

The model

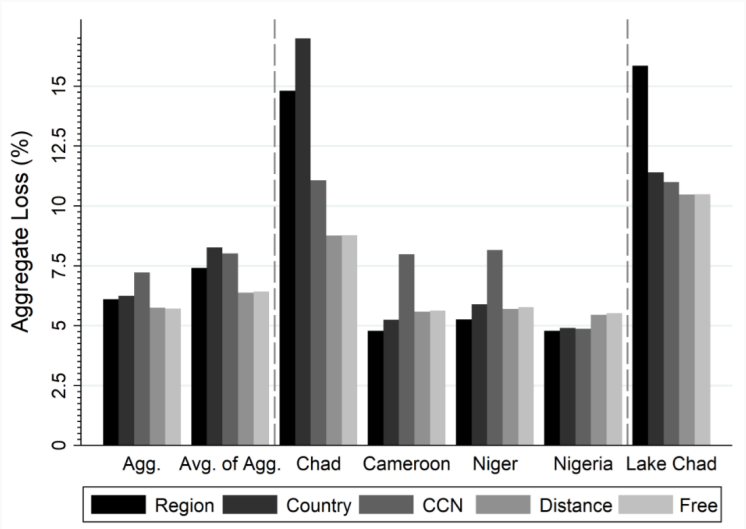
- Many locations.
- Individuals choose where to locate under costly migration frictions.
- Individuals can work in different sectors: fishing, herding, farming, and urban.
- Production in each sector can be traded over space subject to costly trade frictions.
- The lake can impact each sector via reduction in water supply, increases in land supply, reductions in rainfall, increases in temperature.
- These factors are also allowed to impact local productivity and amenities.

The model

What does the lake shrinking change?

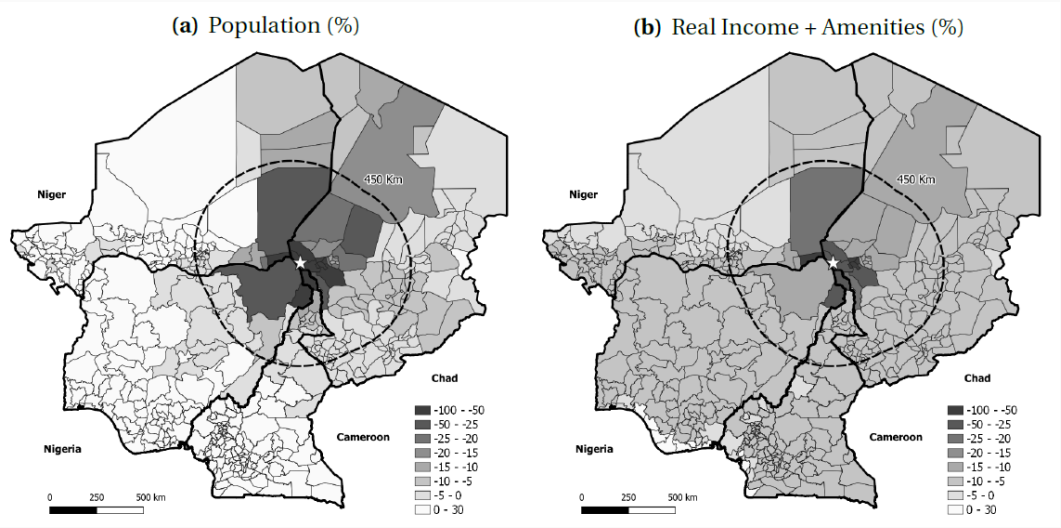
- Trade costs — used to be possible to transport goods over the lake which was cheaper.
- Fishing stock — decreases.
- Land supply — increased positively effecting agriculture and livestock.
- Irrigation — falls in areas that used to be close to the lake. Negatively impacts agriculture and livestock.
- Local climate change — increased temperature and reduced rainfall decreased agricultural and livestock yields.
- Amenities — shore line amenities decrease, and local climate change negatively effects amenities.

Results

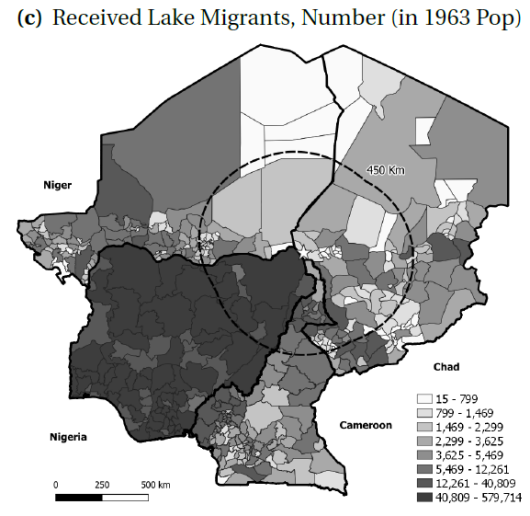


Free = no mig costs; CCN = Cameroon-Chad-Niger free mig; Country = closed borders; Region = region border closed; distance = distanced based mig costs

Spatial impact of Lake Chad shrinking



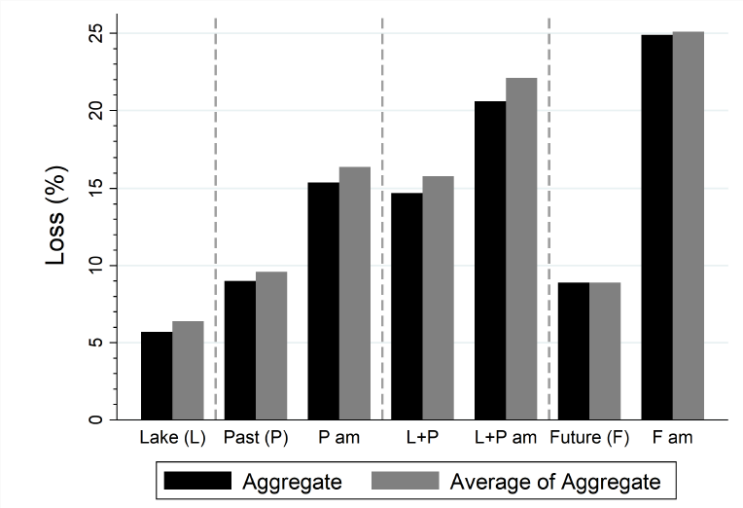
Spatial impact of Lake Chad shrinking



Using the model for other counterfactuals

- Now we have the model we can use it to analyze things other than the lake shrinking.
- Past climate change: From 1960 to 2010 temperatures increased by 1 degree on average and rainfall decreased by 13%.
- Future climate change: From 2010 to 2060 the World Bank predicts further rises of 1.6 degrees and that rainfall increases by 11%.

The impact of future and past climate change



What can we do about it?

- We can also use the model to quantify the effects of policy on mitigating the negative impacts of climate change.
- Lake Chad shrinking is a much more localised effect of climate change — seems reasonable that mitigation policies could be more effective in tackling this.
- Policies
  - Reduced the negative congestion externality.
  - Increase the positive urban agglomeration externality.
  - Improving road infrastructure.
  - Decreasing trade costs.
  - Allowing migration to the rest of the world.

Can policy mitigate the impact of climate change (the lake shrinking)

Reduction in the Loss:	Percentage Points			% of Total Loss		
Policy:	(1) Aggregate	(2) Region Mig	(3) LCR	(4) Aggregate	(5) LCR	(6) LCR/Agg
1. Congestion ext. -0.20 (-0.32 before)	0.9	2.3	0.4	0.16	0.04	0.2
2. Congestion ext. -0.20, Rural only	0.5	1.3	0.2	0.09	0.02	0.2
3. Congestion ext. -0.20, Cities only	0.4	1.2	0.3	0.07	0.03	0.4
4. Agglomeration ext. 0.2 (0.1 before)	0.0	0.2	-0.1	0.00	-0.01	1.0
5. Paving roads around Lake Chad	0.1	0.1	0.2	0.02	0.02	1.1
6. Paving roads lake → largest city	0.2	0.1	0.3	0.03	0.03	0.8
7. Paving roads largest city → lake	0.3	0.2	0.4	0.05	0.04	0.7
8. Region tariffs 10% (20% before)	-0.1	-0.1	-0.1	-0.02	-0.01	0.5
9. RoW tariffs 10% (20% before)	0.1	0.1	0.2	0.02	0.02	1.1
10. RoW cost distance 0.02 (0.03 before)	1.6	1.5	2.5	0.28	0.24	0.9
11. RoW adding international migration	3.0	0.0	2.8	0.52	0.27	0.5

Can policy mitigate the impact of climate change (the lake shrinking)

- Not really.
- The only effective policy was allowing migration out of the region, and that was only 50% effective.
- It seems unlikely that we can (in this case) adapt our way out of the negative impacts of climate change.

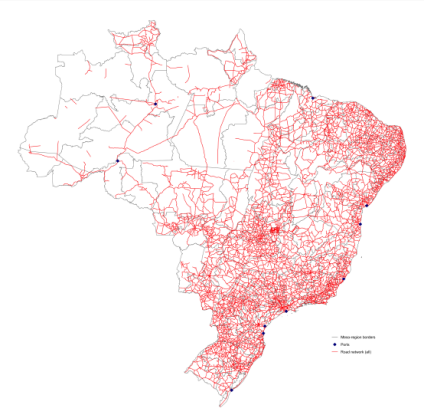
Gollin and Wolfersberger (2024)

Gollin and Wolfersberger (2024)

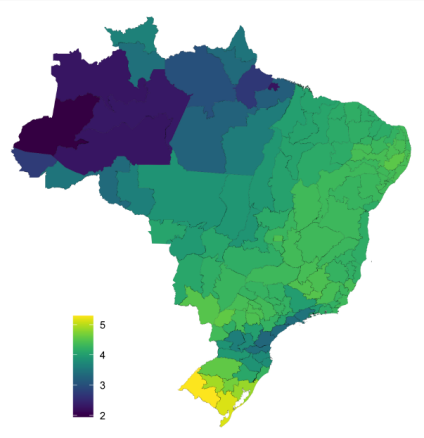
Agricultural Trade and Deforestation: the Role of New Roads.

- The key tradeoff:
  - Roads $\Rightarrow$ development, local increases in GDP per capita.
  - Roads $\Rightarrow$ deforestation, negative global (and local) climate effects.
- Study the impact of roads built between 1995 and 2017 in Brazil.
- Build a quantitative spatial economics model to study this tradeoff.

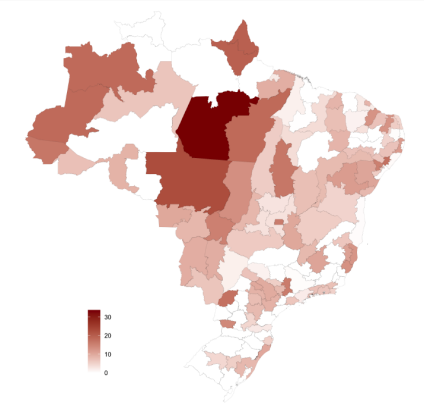
The setting and model inputs



The setting and model inputs — Agricultural productivity



Decreases in transport costs (%)



How can we study this question?

- We have a similar issue as when we studied TransMilano.
- RCTs are not possible, and some empirical study will always be susceptible to spillover/ GE critiques.
- Gollin et al. want to write down a model that allows for the spatially diffuse spillovers from road construction.
- For example: "a road built into one agricultural region may stimulate production in that location to serve distant urban markets. That may in turn alter land use patterns not only in adjacent locations but in other parts of the country that produce similar outputs. Those land use changes may, in turn, drive further impacts in other locations."

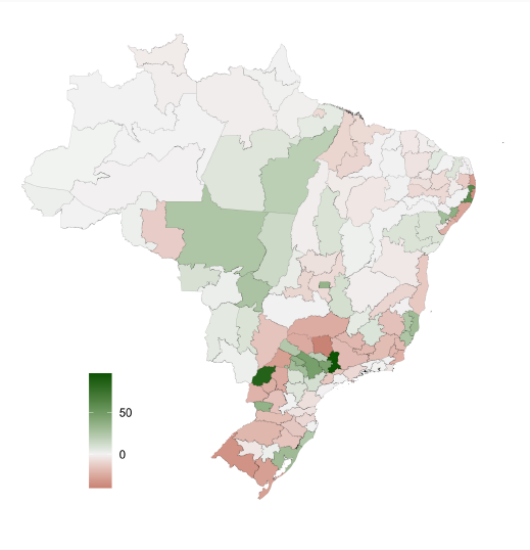
Model: Main ingredients

- Large number of locations (Brazilian meso regions), one trade hub, two sectors (agriculture, non-agriculture).
- Agriculture: Farmers produce output using labor, imported intermediate inputs, and land. They can grow a range of crops depending on land suitability.
- Farmers sell their produce across space subject to trade costs.
- Farmers have a pay a fixed cost to "open" land for use.

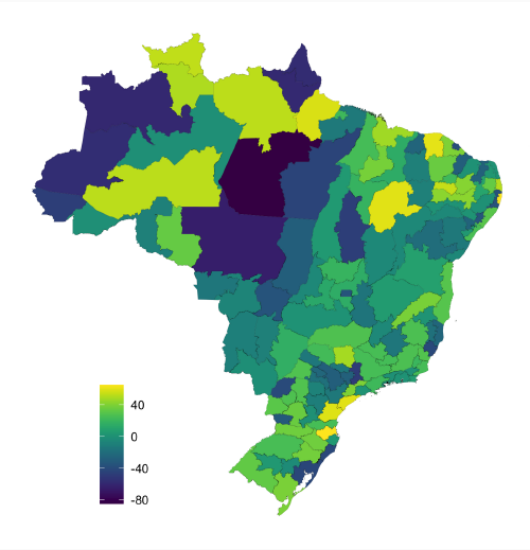
Model: Intuitively what does building roads do

- Building roads reduces transport costs over space.
- Makes it cheaper for farmers to import intermediate good from further away $\rightarrow$ encourages farming in more remote locations.
- Makes it cheaper for farmers to sell their goods $\rightarrow$ encourages farming in more remote locations.
- But different areas vary in (i) their crop suitability, and (ii) the cost of land clearing.
- So reducing transport costs may open more land opportunities and incentivize greater sorting into comparative advantage.

Results — change in forest cover in the absence of new roads since 1995



Results — change in agricultural income in the absence of new roads since 1995



Aggregate results

		Output and Inputs
Forest cover	$\Delta\left(\sum_i F_i\right)$	2.270
Gross ag. income	$\Delta\left(\sum_i \sum_k p_{ik} Q_{ik}\right)$	-3.650
Q1 income	-	-0.692
Q4 income	-	8.254
Ag. exports	$\Delta\left(\sum_k X_k\right)$	-18.082
Ag. consumption	$\Delta\left(\sum_k C_k\right)$	-10.109

Aggregate results

If roads since 1995 had not been built....

- Forest cover would be 2.3% higher.
  - This implies that new roads explain 26% of the total loss in forest cover since 1995.
- Gross income would have been 3.6% lower.
- Agricultural consumption would have been 10.1% lower.
- Is it worth it?

Summary

Summary

- Climate change is having, and will have, the largest impact on the poorest places. And these are the places that have contributed the least to emissions.

- Jedwab et al. (2023) consider the impact of Lake shrinkage.
  - Use empirical analysis and a quantitative model. Difference in differences!
  - Large negative local effects over the whole region.
  - Hard to mitigate these negative impacts.

- Gollin et al. (2024) look at the connection between road building and deforestation in Brazil.
  - Find that more roads $\Rightarrow$ higher incomes but also more deforestation.
  - Potential trade-off between development and environment?