Climate Risks and FDI

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Research Question

- Climate-related risks have increased in recent decades in terms of
  - Frequency of extreme weather events (physical risk)
  - Implementation of green house gas abatement policy (transition risk)
- Research questions:
  - Do climate risks affect FDI flows and MNE affiliate location?
  - If so, to what extent and how is the impact affected by emission productivity and firm exposure to the climate risks?
- Methodology:
  - Build a partial equilibrium model to provide intuition
  - Conduct country, bilateral, industry, firm-level analyses, with interactions of country/industry emission productivity and firm climate risk exposure/awareness

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Contributions and Results

- Little research about the effect of climate change on FDI
  - Barua et al. (2020, country-level), Doytch (2020, country-level), Pankratz and Schiller (2021, global supply chain), Kato and Okubo (2022, input-output linkage model, country-level empirical)
    Our paper provides: Multi-aggregation-level and firm-level analyses with interactions, and model intuitions of both climate risks and interactions
- **Model Predictions**: Target-country physical risk and transition risk directly reduce FDI inflows and MNE affiliates; emission productivity increases them
- Emission productivity can dampen or amplify the impact of climate risks
- **Empirical Findings**: No consistent evidence for statistically significant effects of physical and transition risks on FDI. However, FDI are more likely to react negatively to climate physical risks following Paris Climate Accord among firms more exposed to climate risks. Moreover, countries and industries with higher emission productivity are less likely to experience FDI outflows following extreme weather events.

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Outline

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Environment

- Our model explains:
  1. How many affiliates MNE locates and how much FDI flows to a target country
  2. How the above measures change with physical and transition risks
  3. What is the interaction effect with emission productivity

- Two-country partial-equilibrium model: Horizontal FDI (Helpman, Melitz, and Yeaple, 2004), without goods trade
- Each country: one MNE and N other firms (domestic firms/foreign affiliates)
- Entry mode: M&A with bargained price between MNE and local owners and MNE cost advantage, to calculate FDI inflow (Razin et al, 2007)
- Each affiliate/local firm produces one product variety, monopolistic competition in the product market, standard CES utility function
- Timing: MNE decides to purchase an affiliate or not before disaster state realizes

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Propositions

Proposition 1. Physical risk *When a target country's physical climate risk increases such that the affiliate's expected overhead cost $E(f_i)$ increases, or when a disaster actually happens, it reduces the number of affiliates in the target country.*

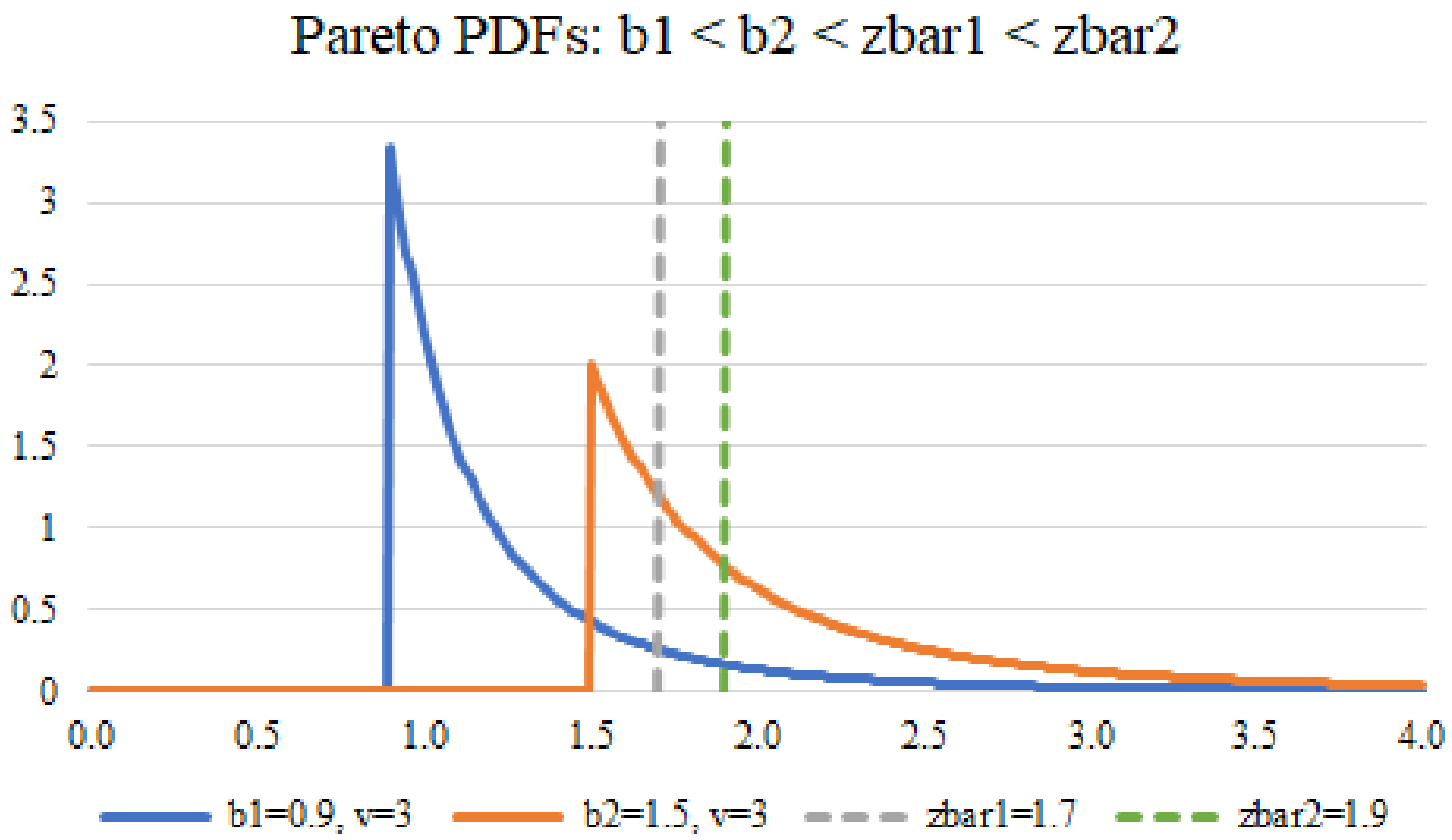
Proposition 2. Transition risk *When climate policies increase emission unit cost r_i, the number of MNE's affiliates in the target country decreases; and the policies **dampen** the effect of physical risk from Proposition 1.*

Proposition 3. Emission Productivity *When technology becomes greener which increases the emission productivity distribution's lower bound b_i (i.e., shifting distribution right and increasing the emission productivity mean), the number of MNE's affiliates in the target country increases; and in this case higher emission productivity **amplifies** the effect of climate risks from Propositions 1 and 2 (**Better Loses**).*

Similar propositions for FDI flows: FDI value calculated from bargained M&A price assuming MNE cost advantage over local owners

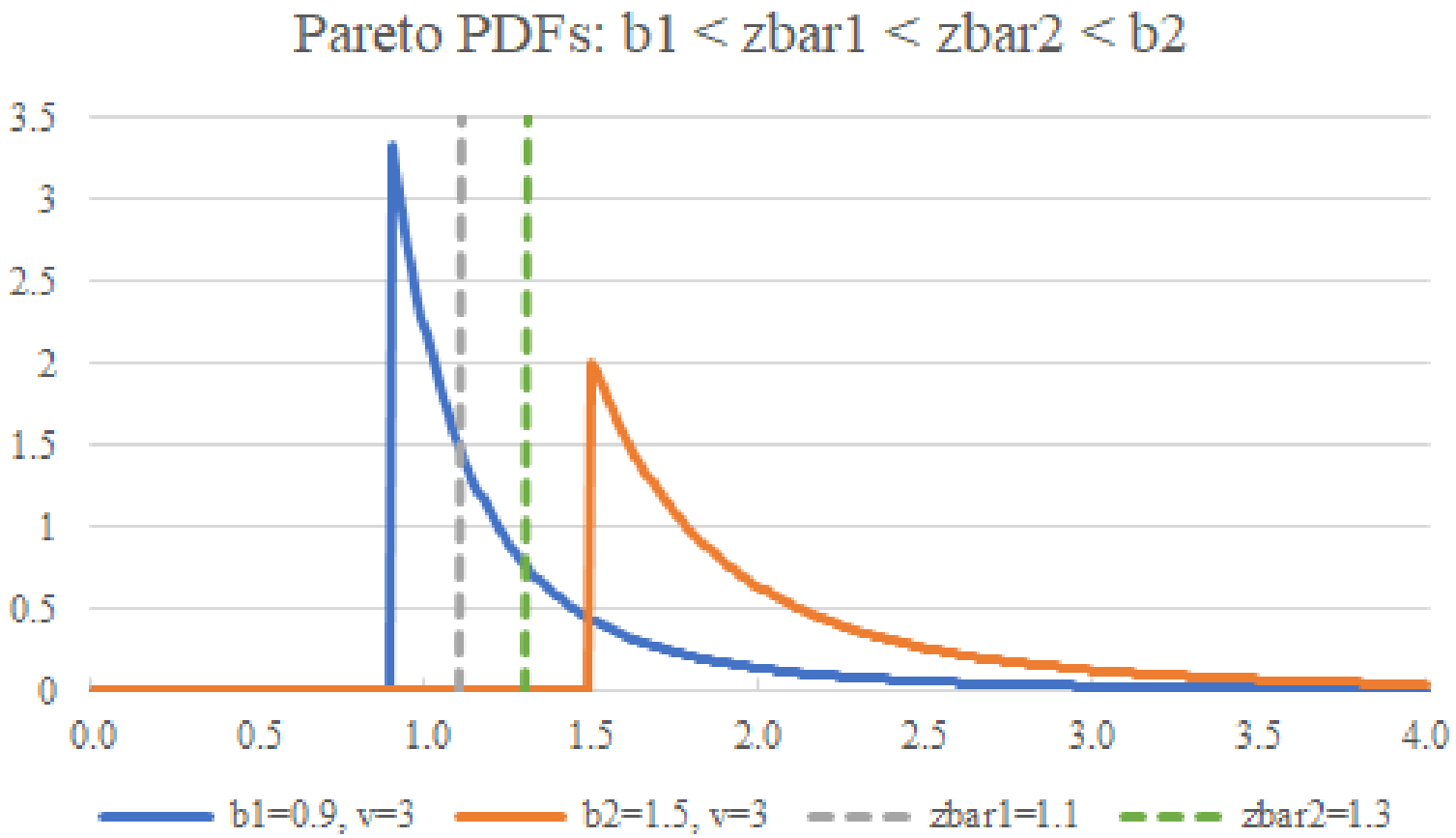
Emission Productivity Interaction: Better Loses

So far we assume that $\bar{z} > b_i$ always holds: More emission-productive industries/target-countries have more exits or FDI reduction due to rising climate risks



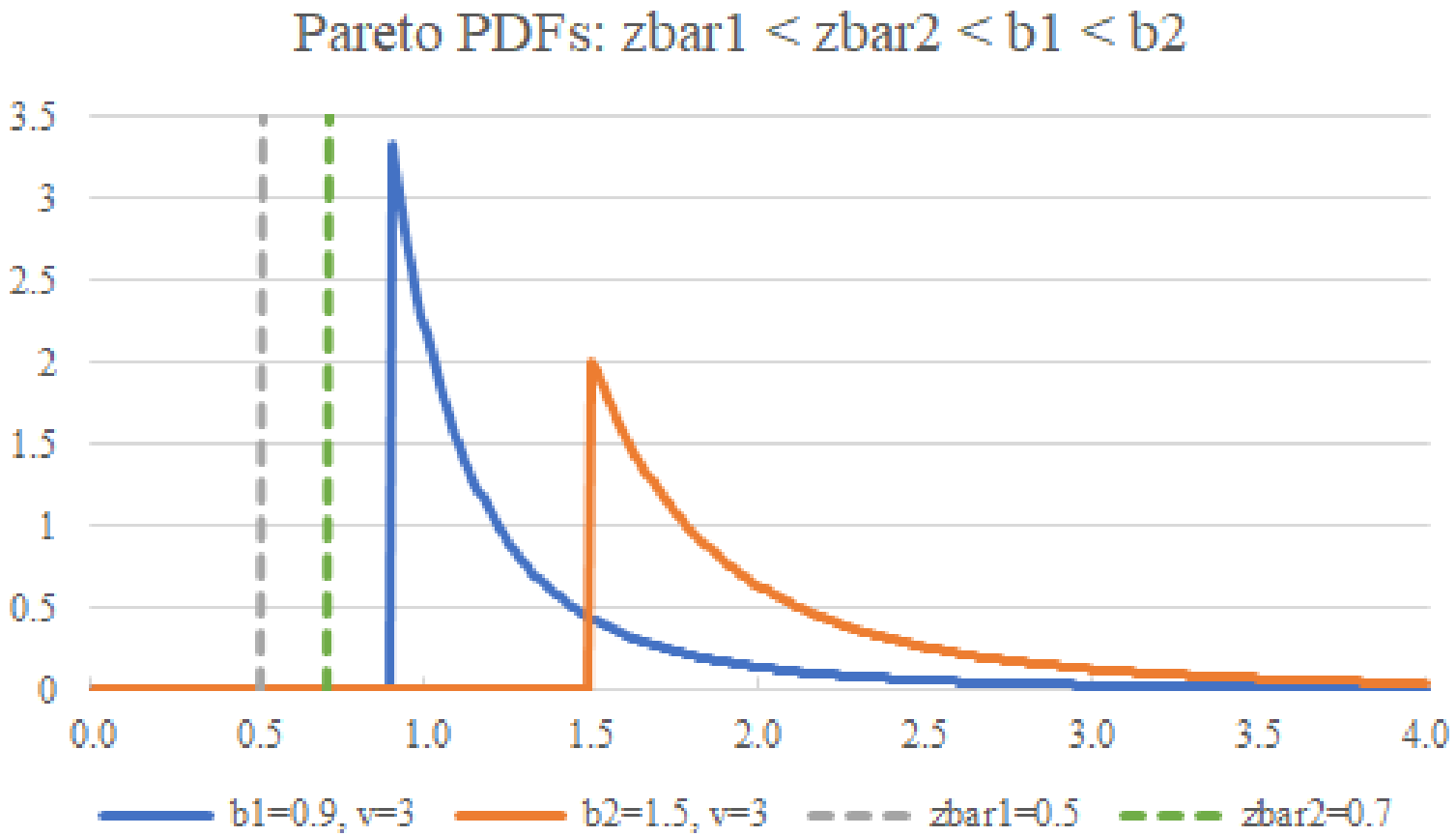
Emission Productivity Interaction: Better Wins

More emission-productive industries/target-countries have fewer exits or less FDI reduction due to rising climate risks



Emission Productivity Interaction: No Effect

$\bar{z}$ is so low (e.g., due to a low r_i or a high market size, or highly emission-efficient industries) that emission-productivity does not matter to the impact of climate risks on FDI



Model Result Summary

- Physical risk ↑, or Transition risk ↑, or actual disaster realizes
  → FDI ↓ (intensive and extensive margins)
- Transition risk may dampen the negative impact of physical risk
- Emission productivity can amplify (*Proposition 3, or Better Loses*) or dampen (*Better Wins*) the impact of climate risks on FDI, depending on the relative position of $\bar{z}$ and b_i ...
- ... with amplification (*Proposition 3, or Better Loses*) being a more likely empirically as on average $b_{AE} > b_{EME}$ *slightly* and both close to 0 in data [Histogram]

Outline

Empirical Strategy

- Target country(i)/country pair(ij) level (ID: within i/within ij):
  $(FDI/GDP)_{igt} = Phy'_{it-1}\Gamma_1 + Tran'_{it-1}\Gamma_2 + \gamma_3 z_{it-1} + Macro'_{it-1}\Gamma_3 + \alpha_i + \beta_t + \delta_{gt} + \epsilon_{it}$,
  where g is country group (AE/EME/LIC)
  - Interaction with z_{it-1}: $\ldots + (z_{it-1}Phy_{it-1})'\Gamma_4 + (z_{it-1}Tran_{it-1})'\Gamma_5$,
  - Also interaction with $Post_{COP21}$ (2016 onward), and cross sectional analysis
- Target Country(i)-industry(k) level (ID: within ik):
  $(FDI/VA)_{ikt} = Phy'_{it-1}\Gamma_1 + Tran'_{it-1}\Gamma_2 + \gamma_3 z_{ikt-1} + Macro_{it-1}\Gamma_4 + \alpha_{ik} + \delta_{kt} + \epsilon_{ikt}$
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- Firm(f) level, headquartered in country j (ID: within fi):
  $\triangle NAffShare_{fjikt} = Phy'_{it-1}\Gamma_1 + Tran'_{it-1}\Gamma_2 + \gamma_3 z_{it-1} + Phy'_{jt-1}\Gamma_4 + Tran'_{jt-1}\Gamma_5 + \gamma_6 z_{jt-1} + \gamma_7 CCR_{ft-1} + Macro_{it-1}\Gamma_3 + \alpha_f + \beta_i + \delta_{ik} + e_t + \epsilon_{fjikt}$
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Climate Disaster Data for Physical Risk

- The Emergency Events Database (EM-DAT) from the Centre for Research on the Epidemiology of Disasters (CRED), U of Louvain
- Worldwide extreme weather events from 1900 to present:
  - 10+ human deaths; or 100+ people injured or left homeless;
  - Declaration by the country of a state of emergency and/or an appeal for international assistance
- For us only climate-related disaster events:
  - Climatological (wildfire and drought);
  - Meteorological (extreme temperatures and storms);
  - Hydrological (flood)
- Monthly number of events, deaths, number of people affected, and economic losses in USD, we aggregate data to country-year level

Climate Policy Data for Transition Risk

- IEA Energy Policies Data
- OECD Environmental Policy Stringency (EPS)
- CO2 tax
- Notre Dame-Global Adaptation Index (ND-GAIN)'s Climate Vulnerability Index

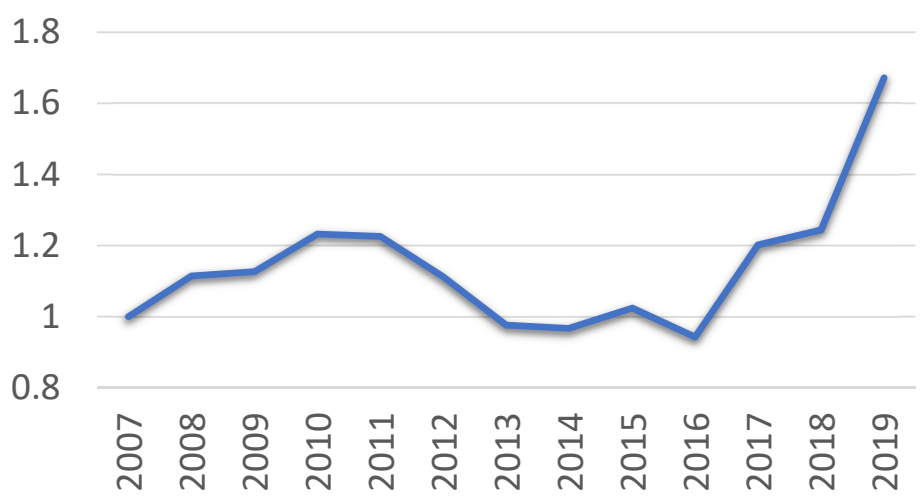
Country-industry Emission Data

- World Input-Output Database (v2016)'s environmental accounts (2000-2016) (Timmer et. al., 2015)
- Emission = *emission relevant total energy use* (*in Terajoule*) − *emission relevant energy use from nuclear and renewables* (*in Terajoule*)
- Country-industry emission productivity $z_{ikt} = Real\ VA_{ikt} / Emission_{ikt}$
- Country emission productivity $z_{it} = RGDP_{it} / \sum_k Emission_{ikt}$

Firm Exposure/Awareness Data

- Climate change exposure index for publicly traded firms, with ISIN numbers (2002-2019) from Sautner et. al. (2021)
- Based on textual analysis of firm conference calls, we use their “risk" measure

Figure: Climate change risk index



- Hypothesis: More exposed firms are more reactive to climate risks
- Dummy (1/0) for higher/lower than median climate change exposure index

FDI Data: Aggregate Levels

- Country level: WDI (1960-2020, 96 countries), divided by GDP
- Bilateral: IMF CDIS (2009-2019, 125 countries), calculated target-country's received FDI share in source-country' total outflow position
- Country-industry: OECD International Direct Investment Statistics Yearbook (2005-2019, 49 industries), classified by ISIC4 codes (2-digit level), manually merged with WIOD industries to be divided by industry value added
- Extensive margins (inflow/outflow) = An indicator (1/0) of whether the inflow is positive (or negative for outflow)

FDI Data: Firm level

- ORBIS (2007-2019), restricted to firms with total assets in excess of 1 billion USD for a given year and excluding OFCs as target countries (but keep firms with headquarters in OFCs)
- For each firm f, Collect information on firm headquarter country j and its industry k, aggregate information on affiliates by target country i and year t
  - Intensive margin = $N\ affiliates_{fjikt} / \sum_i N\ affiliates_{fjikt}$
  - Extensive margins (inflow/outflow) = A dummy (1/0) of whether a firm f has more (or fewer) affiliates in a target country i in a given year t
- Regression sample includes up to 138,824 observations, with 2140 firms located in 31 countries (2 OFCs) and affiliates in 32 countries (10 EMEs, 22 AEs)

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Result Roadmap

- Summarize the coefficients' significance and signs
- Use a heatmap to compare coefficients' magnitudes: Most climate variables between 0 and 1
  - Disasters Only
  - Main effects of climate disasters and policies
  - Interaction effects of emission productivity
- Examine the role of firm-level climate exposure: On average MNEs do not fully take into account the effects of climate risks; so perhaps firm-level climate change risk (CCR) matters. We expect most exposured firms react more

Summary of the Results

Little consistent and significant evidence for the impact of climate risks on FDI. But,

- At aggregate levels, no significant increase in response to climate risks following Paris Climate Accord.
- Firms with high climate risk exposure are more likely to reduce FDI in response to target country's physical climate risks following Paris Climate Accord.
- Country-industry evidence, the most reliable in terms of emission productivity, shows that higher emission productivity leads to higher FDI inflows at both intensive (not statistically significant) and extensive (statistically significant) margins.
- Country-industry main-effect results show that, between advanced and emerging countries, advanced economies are more negatively affected by transition risk. — *Between country groups, "Better Loses"*
- Both Country-industry and Firm evidence show that countries and industries with higher emission productivity are less likely to experience FDI outflows following extreme weather events. — *"Better Wins" across industries and countries.*

Signs and Significance: Intensive Margin

- Count of significantly + coef. / Count of significantly − coef. / Total number of specifications available

	Main effects				Interactions with emission productivity			
	Model	All	AEs	EMEs	Model	All	AEs	EMEs
Effect on FDI (intensive margin)								
Target:								
Climatological	< 0	3 / 8 / 28	2 / 7 / 28	2 / 4 / 28	< 0 or > 0	2 / 2 / 12	2 / 2 / 12	0 / 0 / 12
Meteorological	< 0	1 / 3 / 22	4 / 1 / 22	0 / 4 / 22	< 0 or > 0	2 / 0 / 12	2 / 2 / 12	3 / 2 / 12
Hydrological	< 0	3 / 4 / 28	3 / 7 / 28	4 / 0 / 26	< 0 or > 0	1 / 2 / 12	1 / 2 / 12	1 / 1 / 12
Severity	< 0	2 / 0 / 16	3 / 1 / 16	3 / 0 / 16	< 0 or > 0	1 / 1 / 8	1 / 1 / 8	2 / 0 / 8
Policy Change	< 0	0 / 0 / 8	1 / 0 / 8	0 / 1 / 8	< 0 or > 0	0 / 2 / 8	1 / 2 / 8	2 / 0 / 8
Emission Productivity	> 0	0 / 4 / 12	0 / 4 / 12	0 / 3 / 12	> 0	1 / 4 / 12	2 / 4 / 12	1 / 3 / 8

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	Main effects				Interactions with emission productivity			
	Model	All	AEs	EMEs	Model	All	AEs	EMEs
Effect on FDI (extensive: inflow)								
Target:								
Climatological	< 0	0 / 6 / 16	0 / 7 / 16	2 / 0 / 16	< 0 or > 0	1 / 1 / 9	3 / 0 / 9	0 / 0 / 9
Meteorological	< 0	3 / 3 / 16	1 / 1 / 16	2 / 1 / 16	< 0 or > 0	1 / 0 / 9	0 / 3 / 9	3 / 2 / 9
Hydrological	< 0	1 / 2 / 16	2 / 2 / 16	3 / 1 / 16	< 0 or > 0	0 / 0 / 9	0 / 0 / 9	0 / 2 / 9
Severity	< 0	0 / 0 / 9	0 / 0 / 9	1 / 1 / 9	< 0 or > 0	0 / 0 / 6	0 / 0 / 6	2 / 0 / 6
Policy Change	< 0	0 / 0 / 6	0 / 2 / 6	0 / 0 / 6	< 0 or > 0	0 / 0 / 6	0 / 0 / 6	0 / 0 / 6
Emission Productivity	> 0	2 / 1 / 10	2 / 0 / 10	1 / 0 / 7	> 0	2 / 0 / 9	1 / 0 / 9	2 / 0 / 9
Effect on FDI (extensive: outflow)								
Target:								
Climatological	> 0	1 / 1 / 16	0 / 2 / 16	2 / 1 / 16	< 0 or > 0	0 / 1 / 9	0 / 0 / 9	2 / 0 / 9
Meteorological	> 0	2 / 0 / 16	0 / 0 / 16	1 / 3 / 16	< 0 or > 0	0 / 5 / 9	0 / 3 / 9	0 / 1 / 9
Hydrological	> 0	0 / 0 / 16	0 / 1 / 16	4 / 0 / 16	< 0 or > 0	0 / 5 / 9	0 / 2 / 9	0 / 0 / 9
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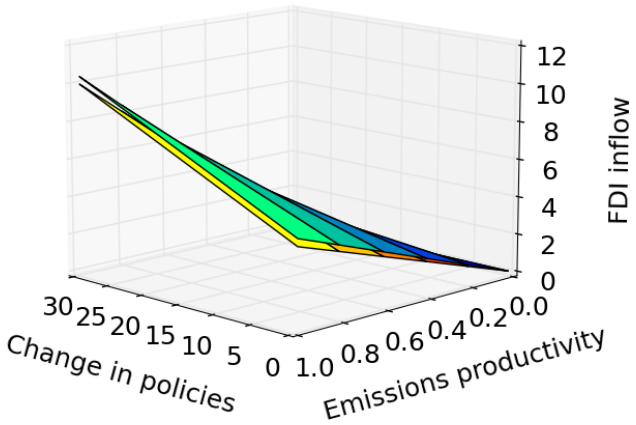
Policy Change	> 0	0 / 0 / 6	3 / 0 / 6	0 / 0 / 6	< 0 or > 0	0 / 0 / 6	0 / 2 / 6	0 / 0 / 6
Emission Productivity	< 0	1 / 3 / 10	1 / 2 / 10	1 / 2 / 10	< 0	1 / 1 / 9	1 / 0 / 9	0 / 0 / 9

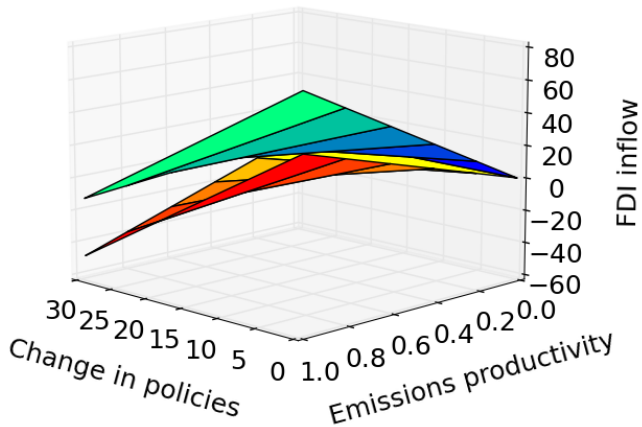
Magnitude: Country-industry

- The effects of control variables and FEs are set to zero
- Blue: disasters are set zero, red: climatological disaster=1, severity=mean

AEs



EMEs



- AEs: more FDI in more energy productive cases, these are also more sensitive to policies (more policies => more FDI), no effect of disasters
- EMEs, more FDI in more energy productive cases, unless there is a change in policy, new policies lower FDI, disasters lower FDI for more energy-productive.

Firm-Level Climate Change Risk Exposure (CCR)

- FEs: firm-target country, firm-year, target country-year, and target industry

	Intensive Margin			
	Full	AE^T	EME^T	OFC^S
CCR ∗ *Climat*	0.00078	0.0017	0.0008	0.00082
CCR ∗ *Meteo*	0.00052***	0.00062**	0.0002*	-0.000011
CCR ∗ *Hydro*	-0.00019	-0.00088	0.000024	-0.0000039
CCR ∗ *Severity*	-0.00011*	0.00016	-0.00014**	-0.000092
CCR ∗ *Policy*	-0.00014*	-0.00015	0.000046	-0.000026
*PostCOP*21∗..				
CCR ∗ *Climat*	-0.0021**	-0.0026*	-0.00054	-0.0025
CCR ∗ *Meteo*	-0.00073***	-0.00076*	-0.00018	-0.000082
CCR ∗ *Hydro*	0.00019	0.00029	-0.000079	-0.00049
CCR ∗ *Severity*	0.0011**	0.0029***	0.00066**	0.0045**
CCR ∗ *Policy*	0.0002*	0.00037	-0.000069	-0.00018
Observations	251587	132899	104765	18522
R^2	0.421	0.434	0.525	0.452

- Firms that are more attentive/exposed to climate risk reduce FDI to AEs following climatological disasters, in recent years

Additional and Robustness tests

- Endogeneity concerns: no reverse causality or spillovers
- Alternative measures of policies: EPS and CO2 tax
- Additional controls: exchange rates, credit ratings, etc.

Reasons for (mostly) negative result

- We did not look in the right place (we looked everywhere we could)
- Firms are not paying attention (evidence that they are starting to)
- Model: Increasing emission productivity over time will reduce response to climate shocks. Indeed, emission productivity is trending up (but not as a result of policies)

Outline

Conclusion

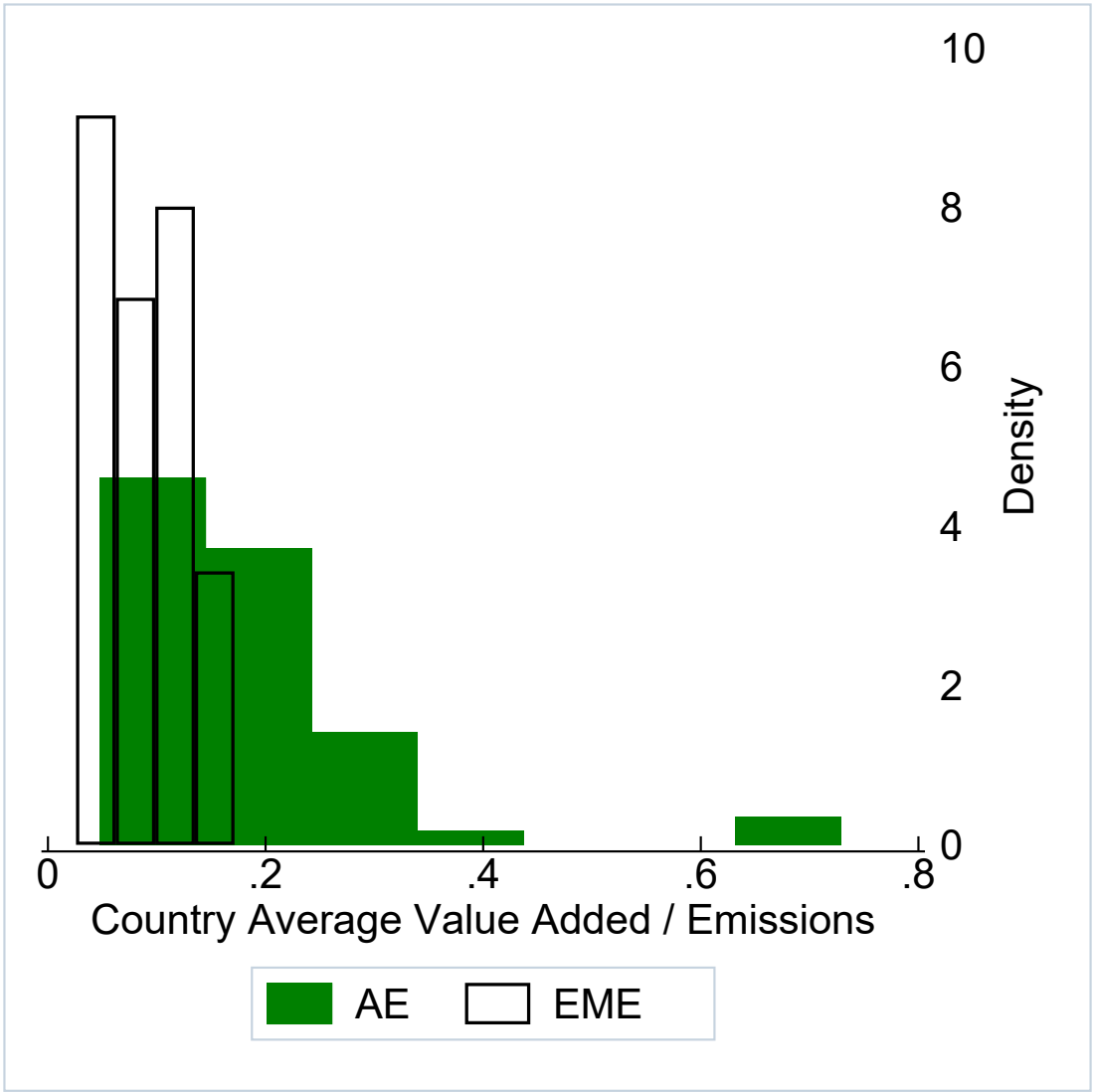
- Do MNEs incorporate climate risks into their FDI decisions? "Not yet."
- Key contributions:
  - One of the first few papers to study the FDI effect of both climate risks
  - At country-, bilateral-, industry- and firm-level, and with interactions with emission-productivity and firm-exposure to climate risk
  - The interaction results are guided by model predictions and highlight the importance of accounting for emission productivity
- Main takeaways:
  - Attention of MNEs to climate risks is rising and more exposed firms react more $\rightarrow$ Future large and abrupt FDI changes are possible as climate risks intensify
  - Future research needs to account for emission productivity, ideally at firm level

Outline

Timing

- An MNE decides whether to purchase a prospective affiliate in the target country h, its production, and price of output
- The target country's extreme weather state (disaster or no disaster) realizes
- If a disaster realizes, the MNE can terminate some affiliates in the target country; otherwise, they continue to operate.

Figure: Histogram of Country Average Emission Productivity by Group



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Climate Disaster Data

- Climate-related disaster events:
  - Climatological (wildfire and drought);
  - Meteorological (extreme temperatures and storms);
  - Hydrological (flood)

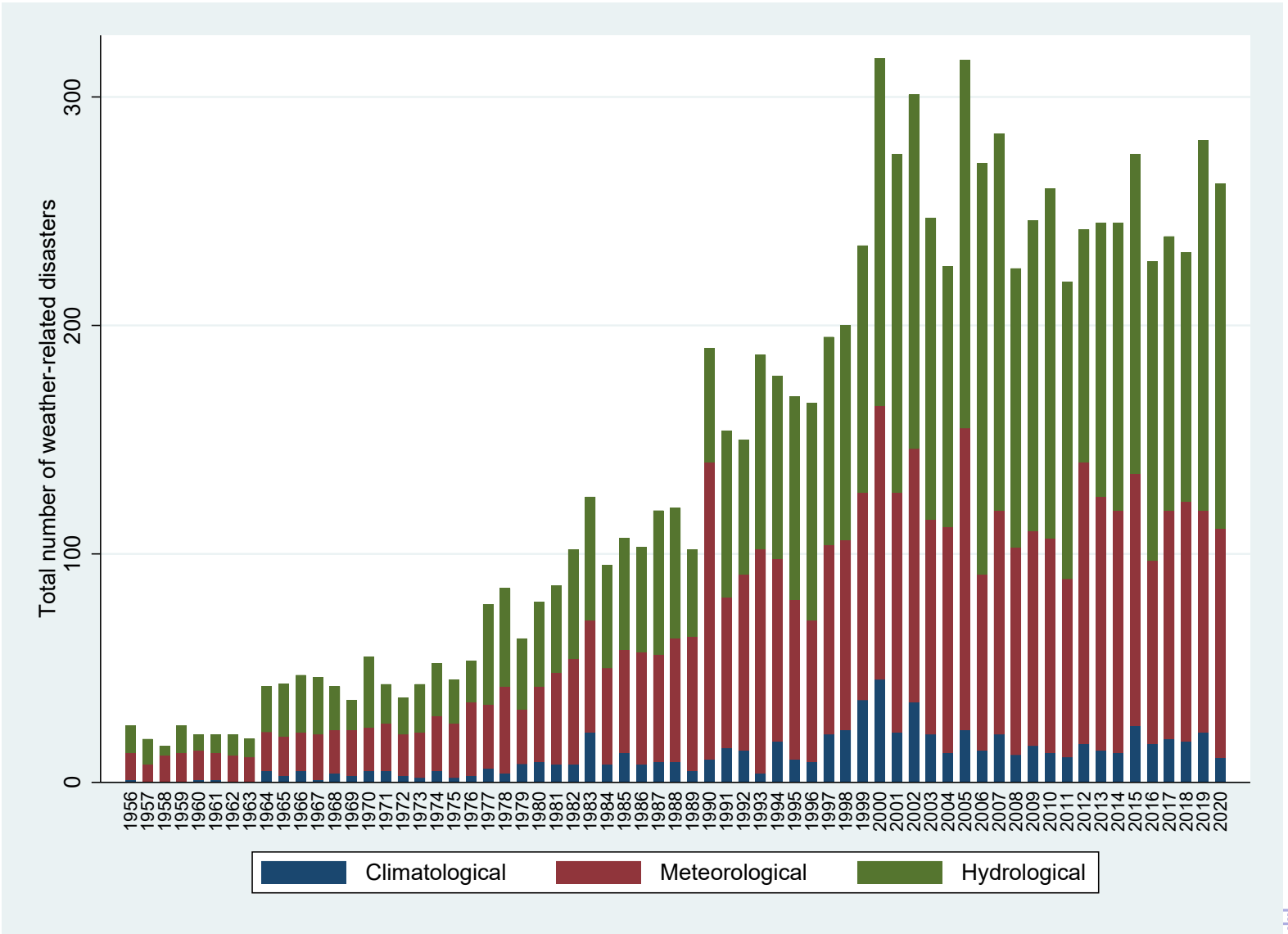
- Monthly number of events, deaths, number of people affected, and economic losses in USD

- Aggregate data to country-year level, and for country-years where no disasters are reported we assume that all indicators are zero — no events

- Economic losses in real USD, by dividing the amount by the U.S. CPI.

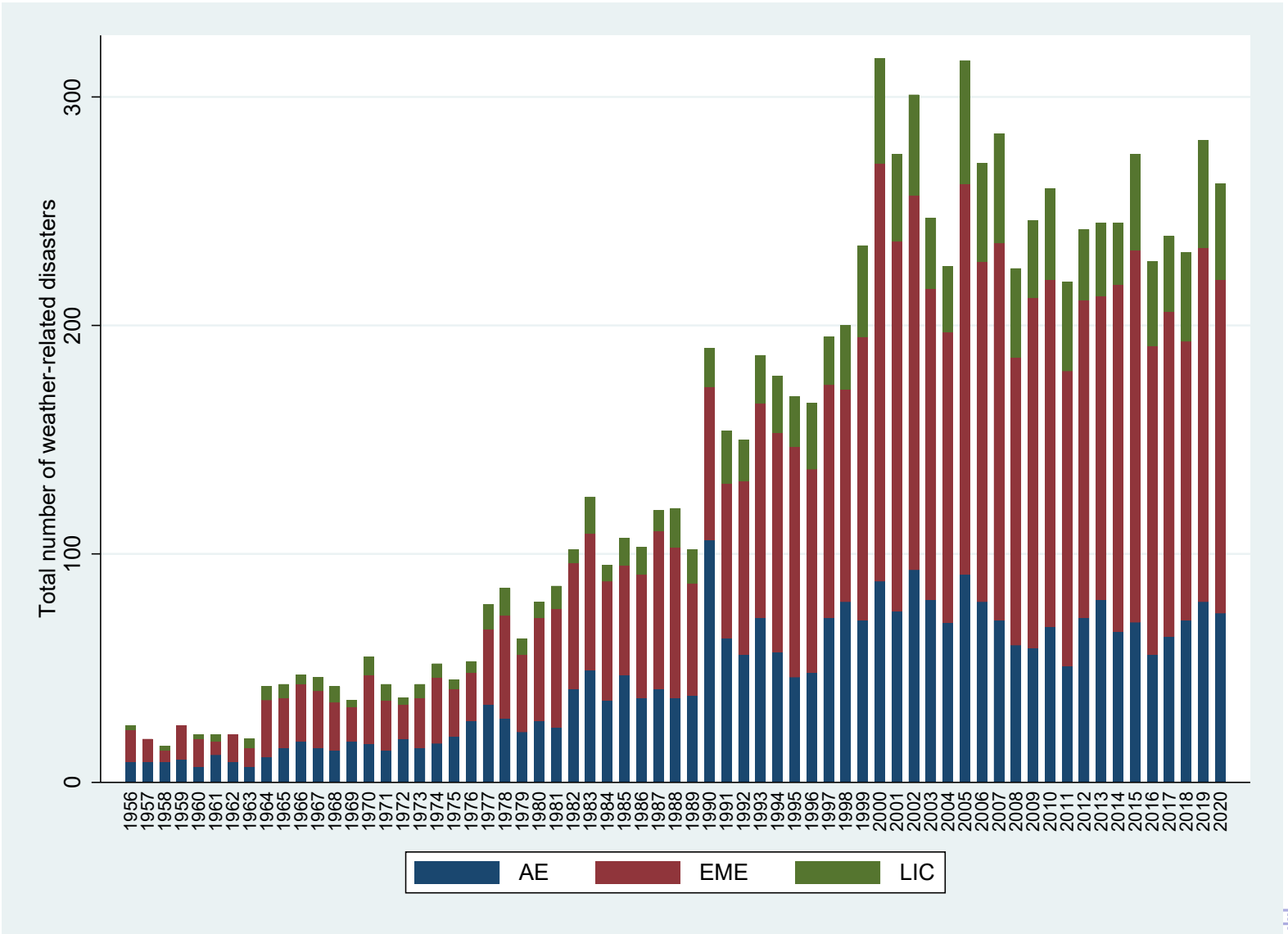
Climate Disaster Data

Figure: Climate-related disaster events by type



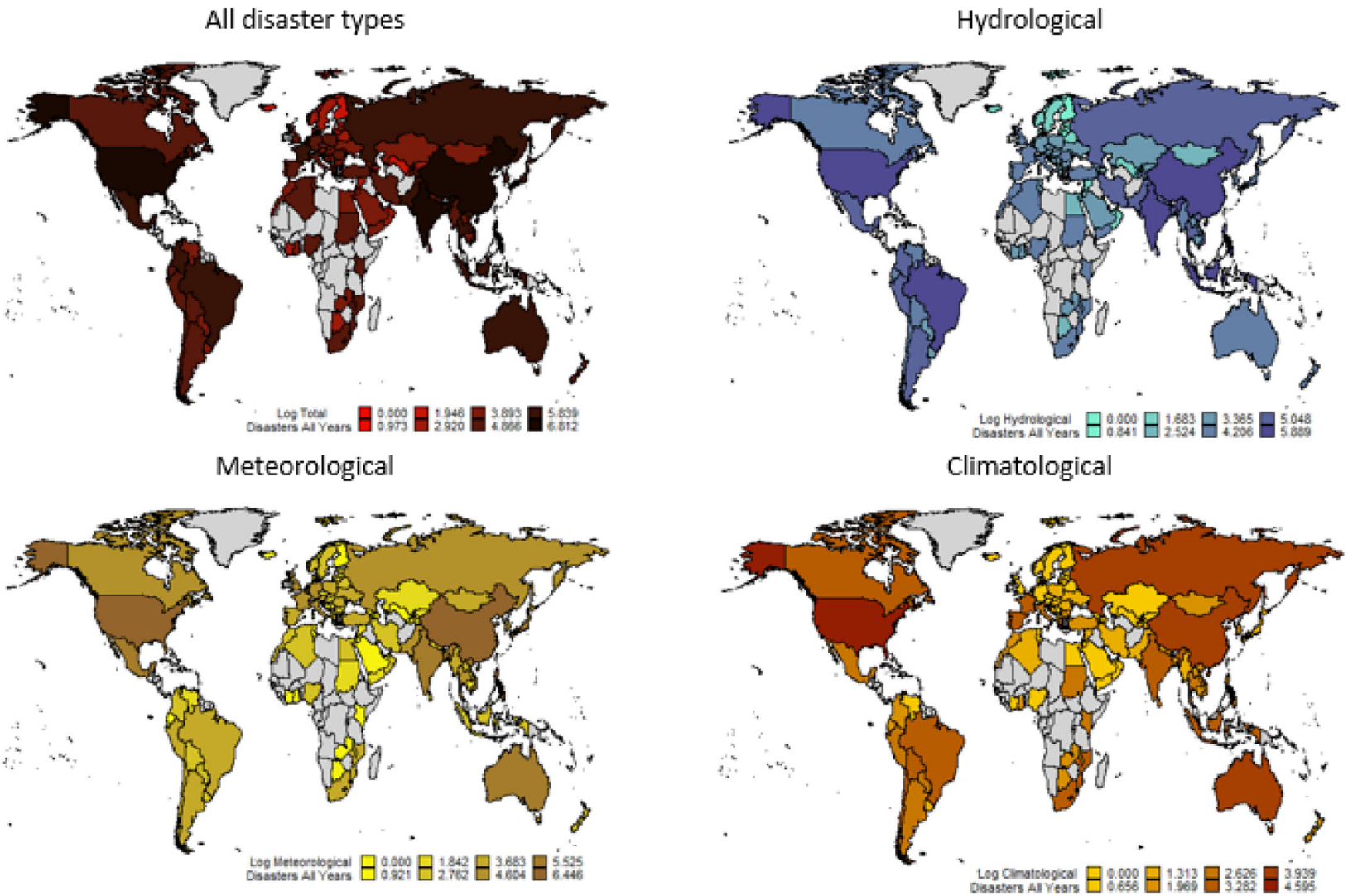
Climate Disaster Data

Figure: Climate-related disaster events by country group



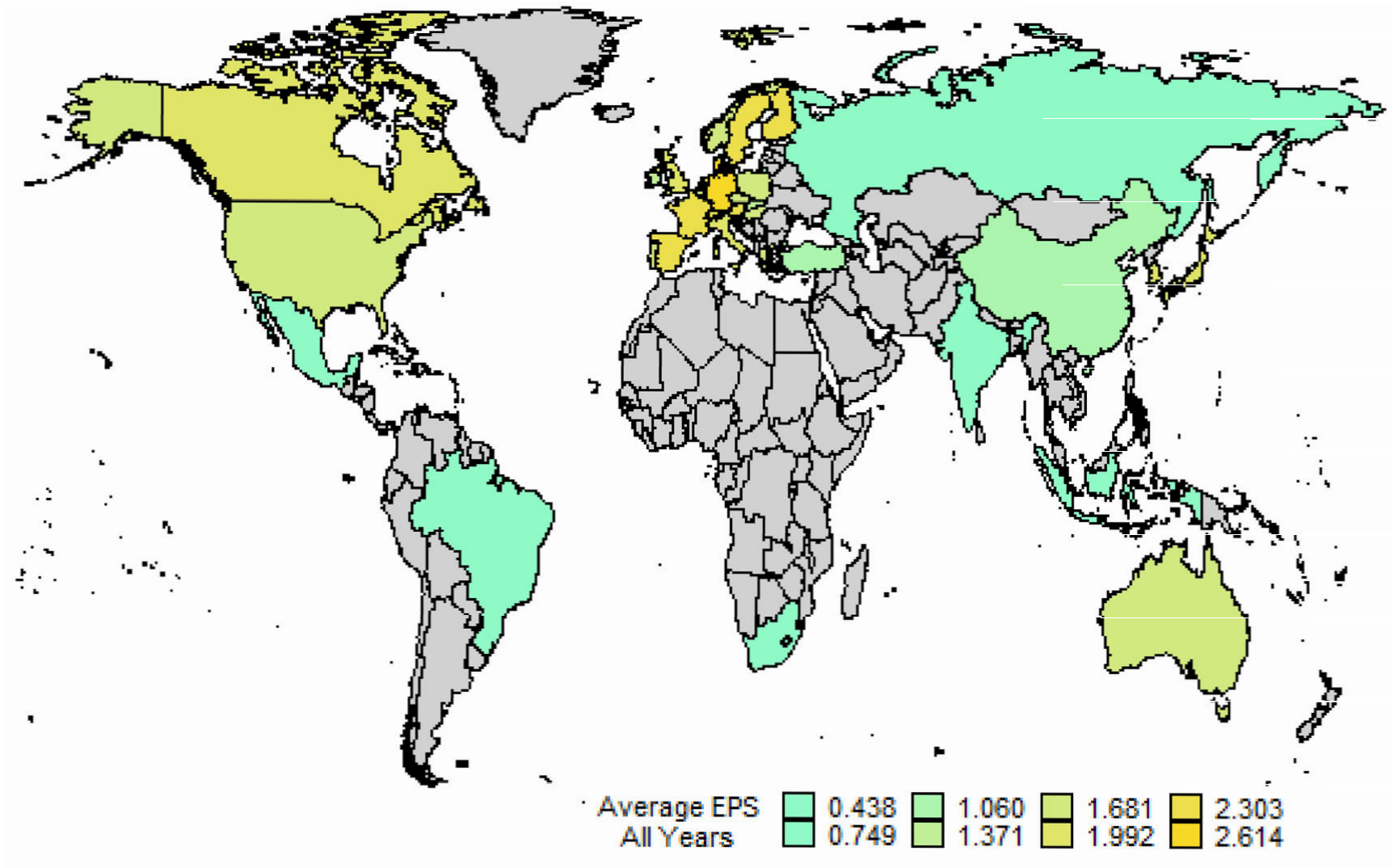
Climate Disaster Data

Figure: Climate-related disaster event map



Climate Policy Data

Figure: Environmental policy stringency map

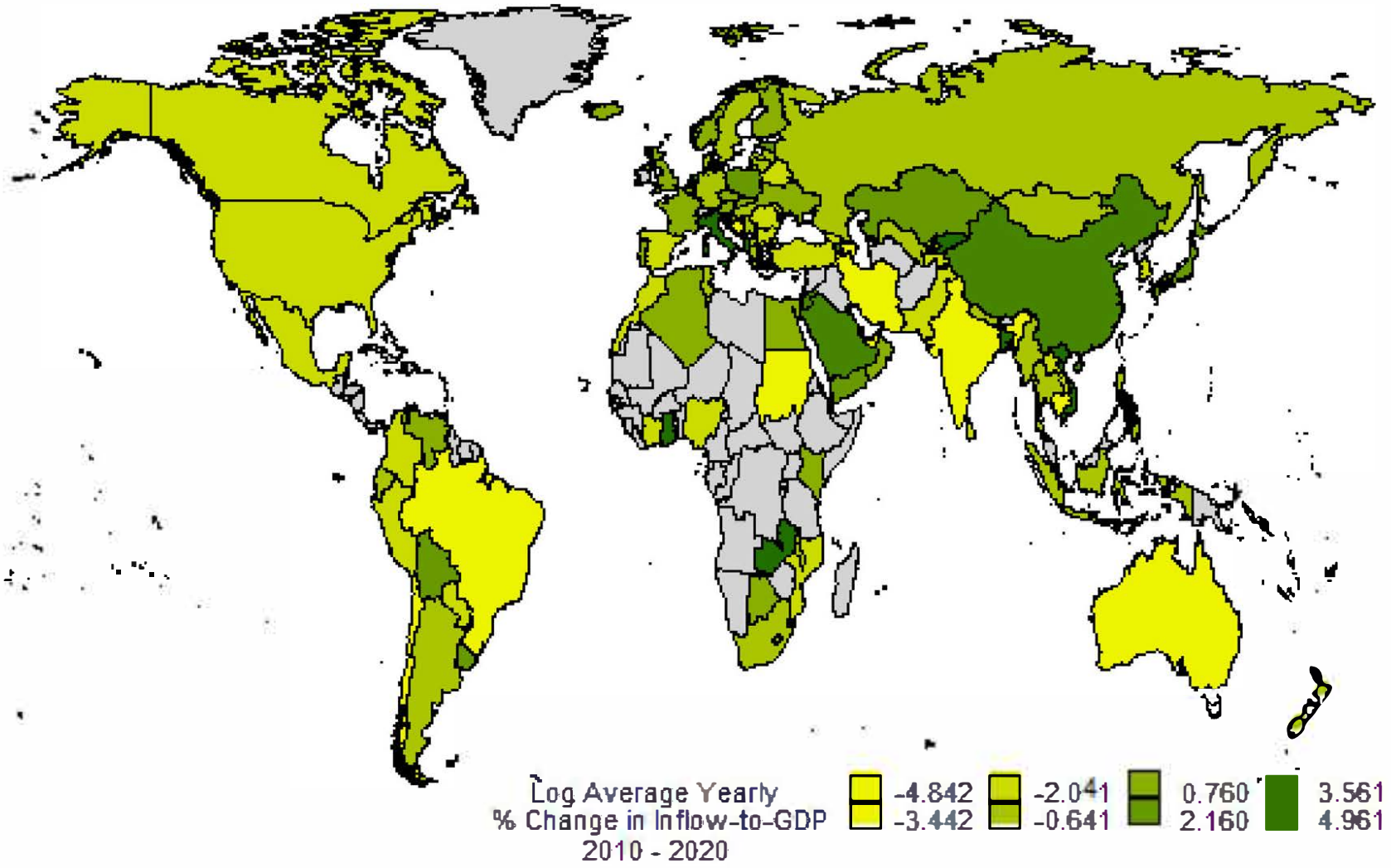


FDI Data: Country level and Bilateral

- WDI (1970-2019, 94 countries)
- Net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor
- Includes equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments
- Divided by GDP
- Bilateral: IMF CDIS (2009-2019, 125 countries), target-country's received FDI share in source-country' total outflow position
- Macro: Trade/GDP, PPI inflation, Real GDP Growth

FDI Data: Country level

Figure: Average annual change in net FDI inflows



FDI Data: Country-industry level

- OECD International Direct Investment Statistics Yearbook 2005-2019, 49 industries

- Classified by ISIC4 codes (2-digit level). Manually merged with WIOD industries to combine with emissions and value added data

FDI Data: Firm level

- ORBIS (2007-2019)
- Restrict to firms with total assets in excess of 1 billion USD for a given year: An unbalanced firm-year panel with 5915 firms from 66 countries with affiliates across 206 countries with the total of over a million of firm-target country-year observations
- For each firm, aggregate information on affiliates by target country and year
- Firm headquarter country and its industry
- Exclude OFCs as target countries, but do keep firms with headquarters in OFCs
- Sample includes up to 138,824 observations, with 2140 firms located in 31 countries (2 OFCs) and affiliates in 32 countries (10 EMEs, 22 AEs).

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FDI Data: Firm level

- An intensive margin: the number of affiliates in a given country in a given year as a share of total number of affiliates that the firm has in that year

- An extensive margin: an indicator of whether a firm has an affiliate in a given country in a given year