

When Vulnerability Suppresses Innovation: Climate Technology across Income Groups

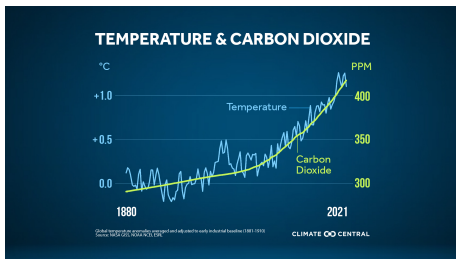
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April 22, 2026

Motivation



Climate Action News Events Resources ▾ Supplier Directory Hydrogen Finance Policy Circul

Climate Innovation Forum 2023

28th June 2023 | London Galkhal
Connecting leaders in business, policy and finance to drive net zero innovation

Renewables can reduce CO₂ emissions by 70% by 2050

Global carbon dioxide (CO₂) emissions from the energy sector can be reduced by 70 per cent by 2050 and completely phased-out by 2060 with a net positive economic outlook – according to new findings

21 March 2017 | Websolutions | [f](#) [t](#) [in](#) [v](#)

- ▶ Climate change is a persistent and uneven shock
- ▶ Technologies help both mitigating and adapting to climate change.
 - ▶ **Mitigation:** Technique effect driver of emissions reductions.
Shapiro and Walker (2018), Brunel and Levinson (2021)
 - ▶ **Adaptation:** Irrigation systems, weather forecasting tools, and climate-resilient crop varieties.
Moscona and Sastry (2023)

★ Need to understand the drivers of innovation and adoption.

Motivation – Going beyond policy

- ▶ Literature focuses on the role of climate regulation addressing market failures & under-investment in climate-related technologies.
 - ▶ Domestic innovation: Jaffe and Palmer (1997), Johnstone, et al. (2010), Brunel (2019)
 - ▶ Spillovers on innovation abroad: Popp (2006), Dechezleprêtre and Glachant (2012)
 - ▶ Effect on transfer of foreign innovation: Dechezleprêtre et al. (2013), Brunel (2019)
- ▶ Limited attention to how climate innovation responds directly to climate vulnerability. Xiao and Fei (2024), Wen et al. (2023), Tran et al. (2025)
 - ▶ Do not fully account for role of policy.
- ▶ Limited evidence on how climate vulnerability affects adoption and diffusion of environmental technology across:
 - ▶ Income levels
 - ▶ Technology types (mitigation vs. adaptation)
 - ▶ Location of innovation (domestic vs. transfer)
 - ▶ Industries

Research Question & Main Findings

Central Question

To what extent does climate vulnerability shape the direction, location, and diffusion of climate innovation beyond the role of policy?

High-income Countries

- ▶ Vulnerability strengthens development of mitigation technologies.
- ▶ Reduces international diffusion of adaptation technologies.
- ▶ Shifts climate innovation toward mitigation and away from adaptation.

Middle-income Countries

- ▶ Constrains mitigation innovation through reduced transfers.
- ▶ Induces local adaptation innovation however policies have no measurable effect.

Data & Empirical Approach

Data

Combine innovation, climate vulnerability, and climate policy data to construct a panel of 79 countries (42 HI & 37 MI [list](#)) from 1995 to 2021.

Measure of Innovation

- ▶ Source: PATSTAT dataset. [more](#) [sum](#)
 - ▶ Technology use determined by the Cooperative Patent Classification
- ▶ Count number of patents filed in country i in each year t
 - ▶ Value of patents measured by family size & triadic patents
 - ▶ New patent or transfer of technology determined by priority.

Measure of Vulnerability

- ▶ Source: Notre Dame Global Adaptation Initiative (ND-GAIN) [sum](#)
 - ▶ Index measuring vulnerability of a country to climate disruptions.
 - ▶ Three pillars: Exposure, sensitivity, & adaptive capacity [more](#)

Measure of Policy

- ▶ Source: IEA/IRENA Joint Policies and Measures database [sum](#)
- ▶ Count of policies in year t .

Estimation Equations

$$PATENTS_{it} = \exp\{\beta_1 CC_{it} + \beta_2 POL_{it} + \beta_3 \mathbf{X}_{it} + \gamma_i + \delta_t\} + \varepsilon_{it}$$

- ▶ $PATENTS_{it}$: Total, New, or Transfers; Mitigation or Adaptation
- ▶ CC : Vulnerability index or logged global temperature anomaly
- ▶ X_{it} : Data Sources
 - ▶ Patent trend: PATSTAT
 - ▶ Lagged patent stock: PATSTAT
 - ▶ GDP: IMF WEO
 - ▶ Trade openness: UN COMTRADE for total trade
- ▶ Country and time fixed effects
 - ▶ Time trend in the case of global temperature anomaly
- ★ Estimate using PPML, with robust standard errors.

High-income Country Results

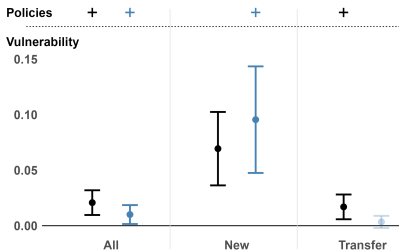
Effects of Vulnerability Beyond Policy

VARIABLES	Mitigation			Adaptation		
	(1) Policy Alone	(2) Baseline Vulnerability	(3) Share of Green Patents	(4) Policy Alone	(5) Baseline Vulnerability	(6) Share of Green Patents
Vulnerability		0.021*** (0.006)	0.025*** (0.009)		-0.031** (0.015)	-0.029*** (0.009)
Policies	0.030*** (0.009)	0.029*** (0.009)	0.010 (0.009)	-0.134** (0.060)	-0.132** (0.060)	-0.013 (0.009)
GDP Per Capita	-0.052 (0.033)	-0.036 (0.032)	-0.033 (0.045)	0.287*** (0.102)	0.257*** (0.095)	0.064 (0.046)
Trade Openness	0.001*** (0.000)	0.001*** (0.000)	0.001 (0.000)	-0.002*** (0.001)	-0.002*** (0.001)	-0.000 (0.000)
Patent Trend	0.964*** (0.034)	0.968*** (0.034)	-0.051*** (0.010)	1.115*** (0.074)	1.109*** (0.073)	0.042*** (0.010)
Lagged Patent Stock	-0.031 (0.078)	-0.021 (0.076)	-0.017 (0.015)	0.117 (0.098)	0.112 (0.098)	0.033** (0.017)
Constant	-0.847 (1.095)	-1.949** (0.984)	1.006 (0.633)	-9.692*** (1.526)	-8.151*** (1.386)	-0.263 (0.652)
Observations	1,081	1,081	1,043	1,063	1,063	1,043
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

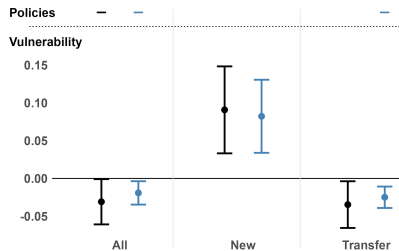
Robust standard errors in parentheses *** p<0.01, ** p<0.05

Diffusion and Adoption of Climate Technology

Mitigation



Adaptation



————— Weighted patents

————— Triadic patents

Results by sector

Middle-income Country Results

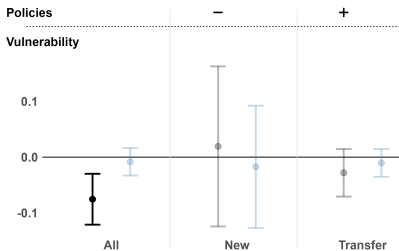
Effects of Vulnerability Beyond Policy

VARIABLES	Mitigation			Adaptation		
	(1) Policy Alone	(2) Baseline Vulnerability	(3) Share of Green Patents	(4) Policy Alone	(5) Baseline Vulnerability	(6) Share of Green Patents
Vulnerability		-0.076*** (0.023)	0.008 (0.014)		-0.023 (0.030)	-0.011 (0.014)
Policies	0.002 (0.017)	0.007 (0.016)	0.020 (0.012)	-0.043 (0.023)	-0.042 (0.023)	-0.014 (0.012)
GDP Per Capita	-0.173 (0.091)	-0.100 (0.091)	0.127*** (0.045)	-0.729*** (0.094)	-0.704*** (0.099)	-0.139*** (0.045)
Trade Openness	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	-0.002 (0.002)	-0.002 (0.002)	-0.001 (0.001)
Patent Trend	1.058*** (0.033)	1.066*** (0.033)	-0.019 (0.011)	1.099*** (0.041)	1.101*** (0.041)	0.024** (0.011)
Lagged Patent Stock	-0.161** (0.070)	-0.130 (0.067)	-0.022 (0.024)	-0.016 (0.050)	-0.012 (0.051)	0.018 (0.024)
Constant	0.952 (0.681)	2.297*** (0.792)	-0.364 (0.658)	2.578*** (0.847)	3.042*** (0.941)	1.619** (0.670)
Observations	883	883	677	782	782	677
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses *** p<0.01, ** p<0.05

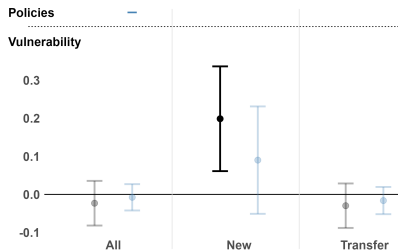
Diffusion and Adoption of Climate Technology

Mitigation



————— Weighted patents

Adaptation



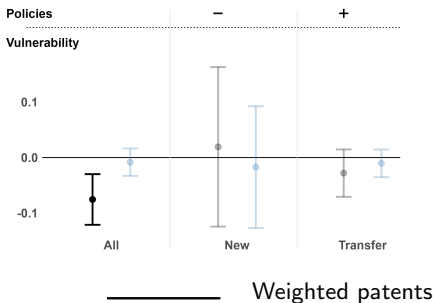
————— Triadic patents

Results by sector

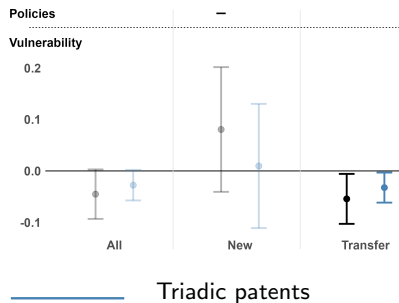
The Role of China

- ▶ China is currently the global leader in green patent filings.

Mitigation



Mitigation (No China)



Results by sector

Conclusion

Climate vulnerability affects green innovation beyond policy, but responses differ sharply across countries.

- ▶ High-income countries respond through increased mitigation innovation.
 - ▶ Reinforces the effects of climate policy.
- ▶ Middle-income countries rely more on lower-value domestic adaptation and face constraints in accessing foreign technologies.
- ▶ China behaves like a high-income country but responds primarily through foreign technology transfer rather than domestic invention.

Policy Takeaway

- ▶ Mitigation policies in high-income countries need to account for vulnerability-driven crowding out of adaptation technologies.
- ▶ Policies aimed at adaptation in middle-income countries need to account for constraints on adoption, not just incentives to innovate.

Thank You

Country list

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High income		Upper middle income		Lower middle income
Australia	Latvia	Albania	Russian Federation	Algeria
Austria	Lithuania	Argentina	Serbia, Rep. of	Egypt, Arab Rep. of
Belgium	Luxembourg	Belarus, Rep. of	South Africa	El Salvador
Canada	Malta	Bosnia and Herzegovina	Thailand	Honduras
Chile	Netherlands, The	Brazil	Turkey	India
Croatia, Rep. of	New Zealand	Bulgaria		Indonesia
Cyprus	Norway	China, P.R.: Mainland		Morocco
Czech Rep.	Panama	Colombia		Nicaragua
Denmark	Poland, Rep. of	Costa Rica		Philippines
Estonia, Rep. of	Portugal	Dominican Rep.		Tunisia
Finland	Romania	Ecuador		Ukraine
France	Saudi Arabia	Gabon		Vietnam
Germany	Singapore	Georgia		
Greece	Slovak Rep.	Guatemala		
Hungary	Slovenia, Rep. of	Jordan		
Iceland	Spain	Kazakhstan, Rep. of		
Ireland	Sweden	Malaysia		
Israel	Switzerland	Mexico		
Italy	United Kingdom	Moldova, Rep. of		
Japan	United States	Montenegro		
Korea, Rep. of	Uruguay	Peru		

Patent Summary Statistics for Selected Countries

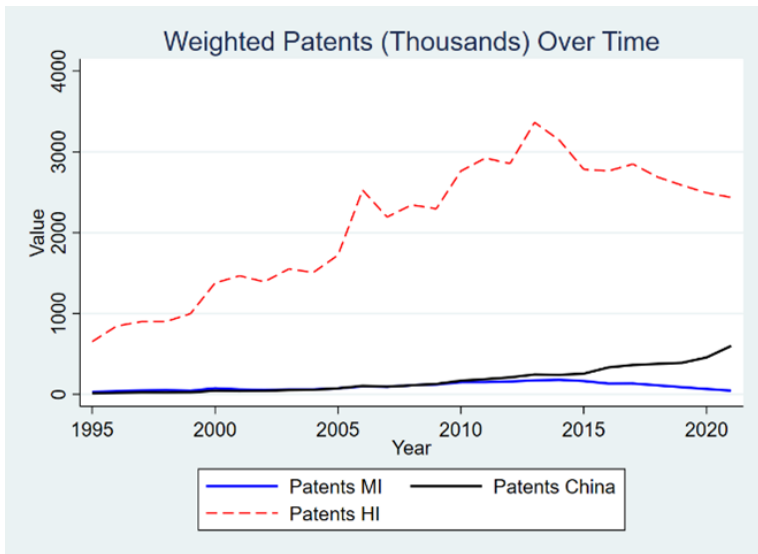
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		Value-weighted count				Simple count
		Mean	Std. Dev.	Min.	Max.	Mean
High-income	Germany	126,113	35,317	54,384	186,850	18,879
	New	20,215	7,887	7,812	30,617	5,945
	Transfer	105,898	28,787	46,572	160,630	12,935
	United States	173,864	94,022	37,669	351,939	25,254
	New	30,473	8,042	17,087	42,762	7,080
	Transfer	143,391	87,095	19,056	313,327	18,174
Upper-middle	China	172,967	158,500	12,575	599,348	86,984
	New	84,403	118,007	990	453,941	75,783
	Transfer	88,563	52,273	11,585	163,988	11,201
	Mexico	17,125	9,015	3,190	31,001	1,085
	New	548	449	26	1,563	95
	Transfer	16,577	8,644	3,004	29,438	990
Lower-middle	India	1,597	4,291	2	21,295	138
	New	105	275	0	1,335	24
	Transfer	1,493	4,027	0	19,960	113
	Egypt	378	353	0	1,134	23
	New	15	27	0	92	3
	Transfer	363	336	0	1,124	21

Countries with the Most Patent Filings Back

Ranking	Total Patent		Total Patent (Weighted)	
	1995	2021	1995	2021
1	JPN (16931)	CHN (450740)	DEU (54384)	CHN (599348)
2	DEU (8093)	USA (41184)	USA (43248)	USA (245158)
3	USA (7269)	JPN (35858)	AUT (40248)	JPN (144466)
4	ESP (4563)	KOR (30489)	ESP (40066)	DEU (128347)
5	AUT (4530)	DEU (25224)	JPN (36221)	GBR (124518)
6	GBR (4085)	GBR (23269)	DNK (35219)	ESP (122867)
7	DNK (3966)	ESP (23092)	FIN (32941)	DNK (121929)
8	FRA (3952)	LUX (22812)	PRT (31537)	PRT (121903)
9	FIN (3862)	NLD (22777)	GRC (30537)	LUX (121756)
10	GRC (3701)	DNK (22723)	GBR (30297)	NLD (121641)

Patents Over Time by Country Income

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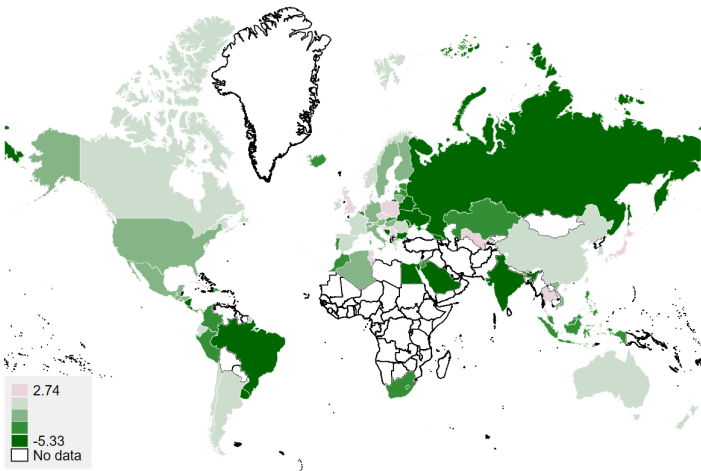
Construction of Vulnerability Index back

Table 1 ND-GAIN Vulnerability Indicators

Sector	Exposure component	Sensitivity component	Adaptive Capacity component
Food	Projected change of cereal yields	Food import dependency	Agriculture capacity (Fertilizer, Irrigation, Pesticide, Tractor use)
	Projected population change	Rural Population	Child malnutrition
Water	Projected change of annual runoff	Fresh water withdrawal rate	Access to reliable drinking water
	Projected change of annual groundwater recharge	Water dependency ratio	Dam capacity
Health	Projected change of deaths from climate change induced diseases	Slum population	Medical staffs (physicians, nurses and midwives)
	Projected change of length of transmission season of vector-borne diseases	Dependency on external resource for health services	Access to improved sanitation facilities
Ecosystem services	Projected change of biome distribution	Dependency on natural capital	Protected biomes
	Projected change of marine biodiversity	Ecological footprint	Engagement in International environmental conventions
Human Habitat	Projected change of warm period	Urban concentration	Quality of trade and transport-related infrastructure
	Projected change of flood hazard	Age dependency ratio	Paved roads
Infrastructure	Projected change of hydropower generation capacity	Dependency on imported energy	Electricity access
	Projection of Sea Level Rise impacts	Population living under 5m above sea level	Disaster preparedness

Country Vulnerability Change 1995-2021 Back

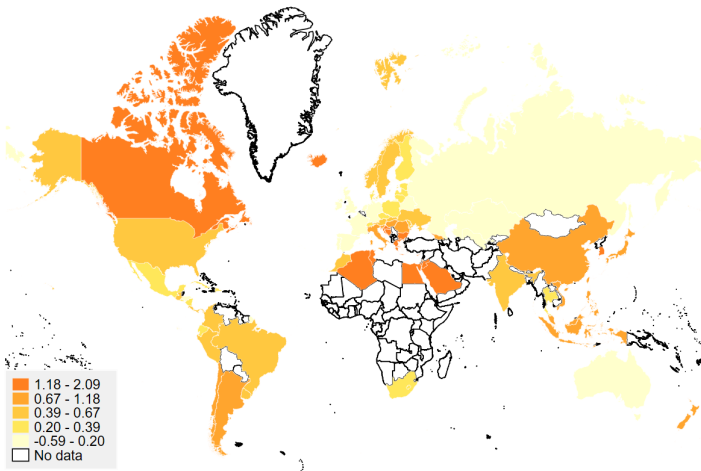
Climate Vulnerability Change 1995 - 2021



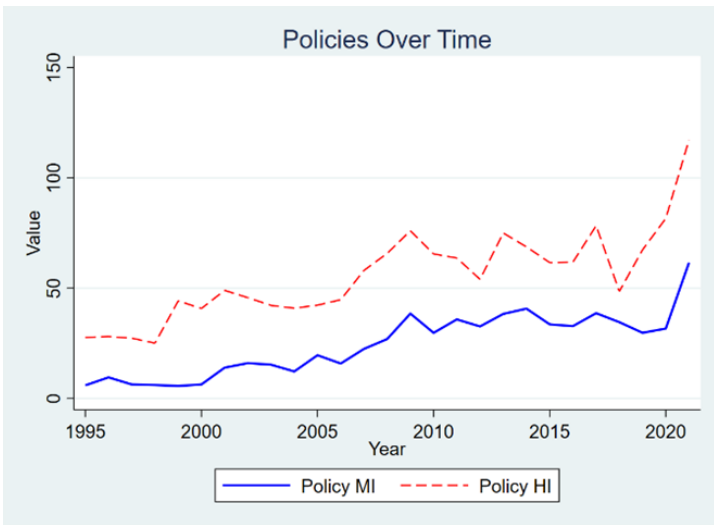
Country Temperature Change 1995-2021

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Temperature Change 1995 - 2021

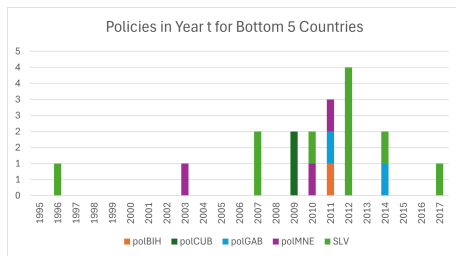
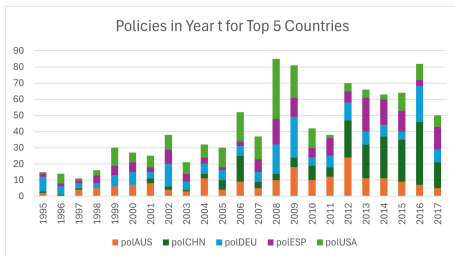


Climate Policy by Income Group [Back](#)



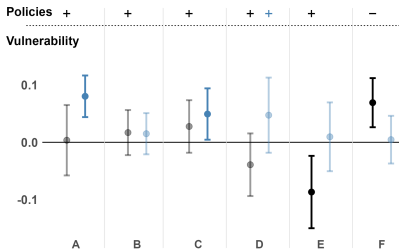
Policy data and measure Back

- ▶ Source: IEA/IRENA Joint Policies and Measures database
 - ▶ Count of policies in year t
 - ▶ Stock of policies enacted up to year t
 - ▶ Account for domestic policies and policies in the rest of the world

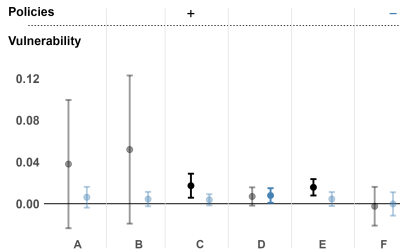


High-income Mitigation by Sector Back

New



Transfer



Weighted patents

Triadic patents

Industry codes:

A: Agriculture

D: Electricity

B: Mining

E: Water & Waste

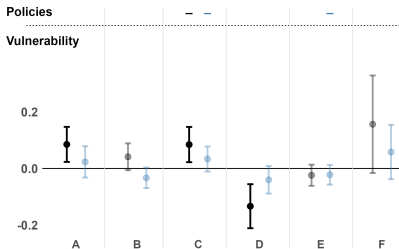
C: Manufacturing

F: Construction

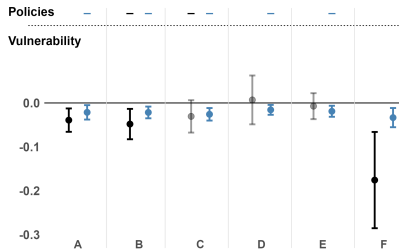
High-income Adaptation by Sector

[Back](#)

New



Transfer



————— Weighted patents

————— Triadic patents

Industry codes:

A: Agriculture

D: Electricity

B: Mining

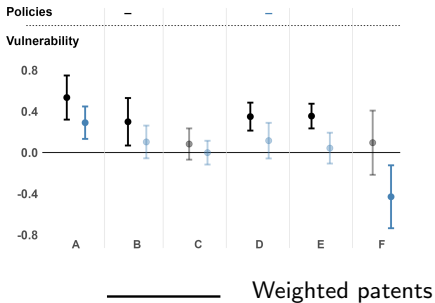
E: Water & Waste

C: Manufacturing

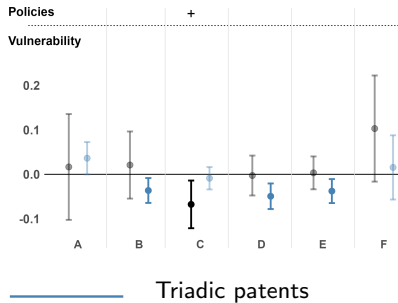
F: Construction

Middle-income Mitigation by Sector Back

New



Transfer



Industry codes:

A: Agriculture

D: Electricity

B: Mining

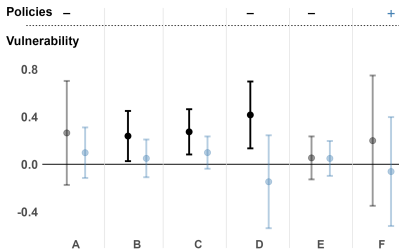
E: Water & Waste

C: Manufacturing

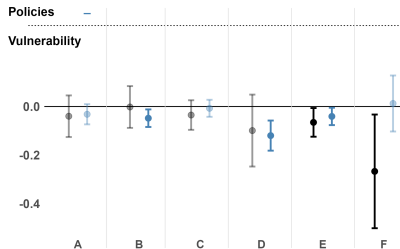
F: Construction

Middle-income Adaptation by Sector Back

New



Transfer



————— Weighted patents

————— Triadic patents

Industry codes:

A: Agriculture

D: Electricity

B: Mining

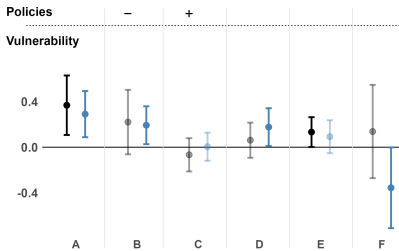
E: Water & Waste

C: Manufacturing

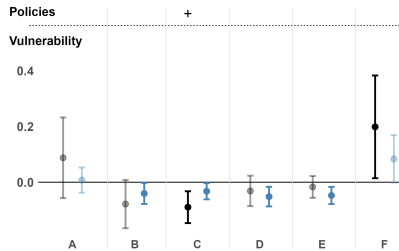
F: Construction

Middle-income (No China) Mitigation by Sector Back

New



Transfer



Weighted patents

Triadic patents

Industry codes:

A: Agriculture

D: Electricity

B: Mining

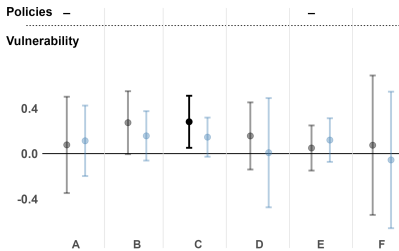
E: Water & Waste

C: Manufacturing

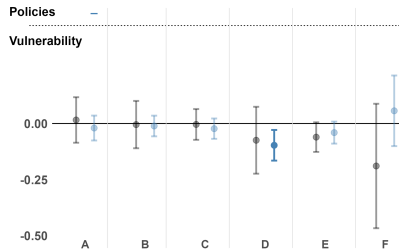
F: Construction

Middle-income (No China) Adaptation by Sector Back

New



Transfer



Weighted patents

Triadic patents

Industry codes:

A: Agriculture

D: Electricity

B: Mining

E: Water & Waste

C: Manufacturing

F: Construction