Climate change increases bilateral trade cost

Maximilian Huppertz

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Motivation

- Trade networks: nodes (e.g., countries) and links (trade cost)

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- Climate change affects productivity
- Mechanisms apply to almost any kind of economic activity
- Question: Does climate change affect trade cost as well?
- Implication: Underestimate welfare impact of climate change

Roadmap of the paper

- Assemble data on trade, weather spanning the last $\approx$ 200 years

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- Assemble data on trade, weather spanning the last $\approx$ 200 years
- Augmented gravity equation $\rightarrow$ climate change affects trade cost
- Embed in standard model of international trade
- Ignoring this effect $\rightarrow \approx$ 10 percent underestimate of welfare impact
- Simple plug-and-play methodology

Data

Data

- 1827–2014 trade flows from CEPII TRADHIST (Fouquin and Hugot 2016)

▸ Country counts ▸ Unmatched flows ▸ Global temperature

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- Country boundaries from GADM (Global Administrative Areas 2022)
- Current trade shares from ITPD (Borchert et al. 2021; Borchert et al. 2022)

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Reduced form:

Climate change increases trade cost

Empirical framework: Gravity estimation

- Gravity equations (Head and Mayer 2015)

$$X_{nit} = G_t S_{it} M_{nt} \phi_{nit}$$

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$$\phi_{nit} = d_{ni}^{\alpha_t + \delta_1 \Delta T_{it} + \delta_2 \Delta T_{nt}} e^{\mathbf{C}'_{nit}\beta}$$

- Yields estimating equation ($\tilde{d}_{ni} \equiv \log(d_{ni})$)

$$\mathbb{E}(X_{nit}|\mathbf{D}_{nit}) = \exp\left\{\gamma_{it} + \xi_{nt} + \alpha_t \tilde{d}_{ni} + \delta_1 \tilde{d}_{ni} \Delta T_{it} + \delta_2 \tilde{d}_{ni} \Delta T_{nt} + \mathbf{C}'_{nit}\beta\right\}$$

Identification

- Recall

$$\mathbb{E}\left(X_{nit}|\mathbf{D}_{nit}\right) = \exp\left\{\gamma_{it} + \xi_{nt} + \alpha_t \tilde{d}_{ni} + \delta_1 \tilde{d}_{ni} \Delta T_{it} + \delta_2 \tilde{d}_{ni} \Delta T_{nt} + \mathbf{C}'_{nit}\beta\right\}$$

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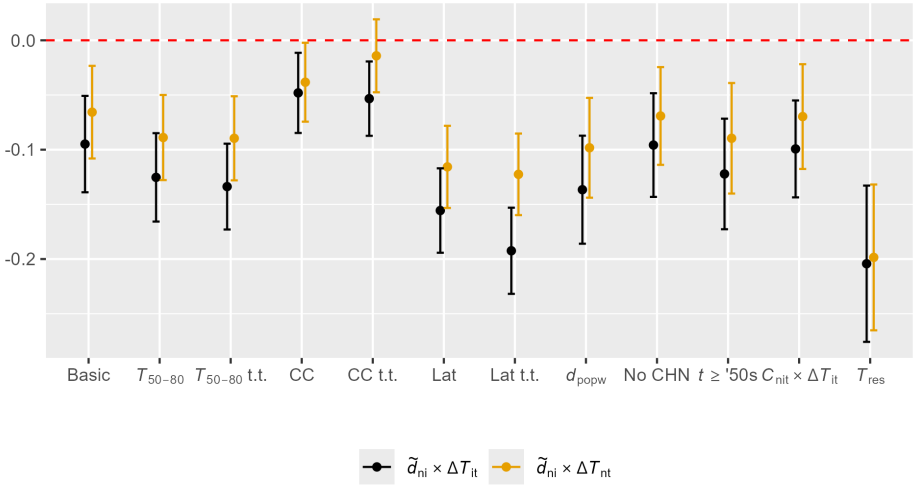
- RHS becomes

$$= \exp\left\{\gamma_{it} + \xi_{nt} + \alpha_t \tilde{d}_{ni} + \left(\sum_{D=1}^{10} \alpha_D \tilde{d}_{ni} + \tau_D t \tilde{d}_{ni}\right) + \delta_1 \tilde{d}_{ni} \Delta T_{it} + \delta_2 \tilde{d}_{ni} \Delta T_{nt} + \mathbf{C}'_{nit}\beta_t\right\}$$

Effect of climate change on trade cost



▸ ΔT_{ct} distribution ▸ Table

Mechanisms

- Port costs matter for shipping costs (Brancaccio et al. 2020)

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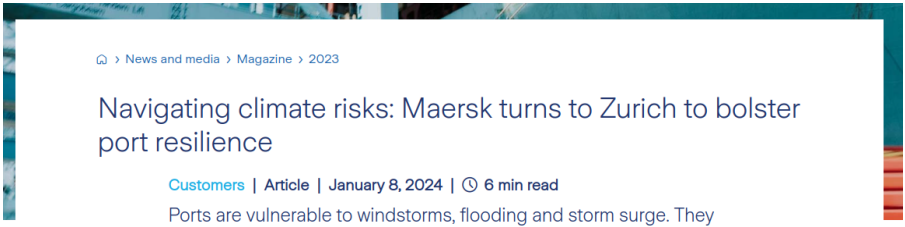
- Climate change affects labor productivity (e.g. Adhvaryu et al. 2019; Carleton and Hsiang 2016; Huppertz 2024; Nath 2020; Somanathan et al. 2021; Zhang et al. 2018)
- Extreme weather affects ports (Astier 2025; Massoni 2025)



▸ Sea only vs long distance trade ▸ Donut holes ▸ UNCTAD results ▸ Adaptation

Structural model:
Welfare implications

Model

- What if we went from period t climate to period $s < t$ climate?

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- Change in trade shares $\pi_{nit} = X_{nit}/X_{nt}$ is

$$\hat{\pi}_{nit} = \frac{\hat{A}_{it}\left(\hat{\tau}_{nit}\hat{w}_{it}\right)^{-\theta}}{\sum_{k=1}^{N}\pi_{nkt}\hat{A}_{kt}\left(\hat{\tau}_{nkt}\hat{w}_{kt}\right)^{-\theta}}$$

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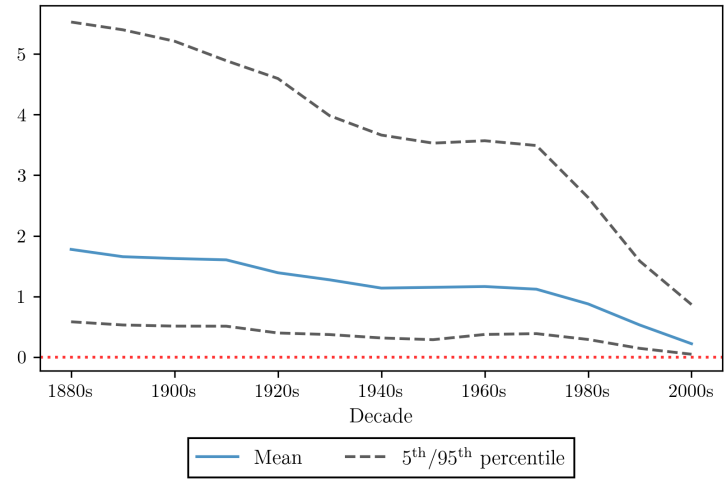
- For now, productivity unchanged ($\hat{A}_{it} = 1$)

Welfare change (percent) across decades



▸ Map ▸ Correlates of welfare changes

Underestimating climate change

- Estimates of productivity channel welfare effects vary (e.g. Costinot et al. 2016; Nath 2020; Bilal and Känzig 2024)

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- Estimate productivity impact similar to Nath et al. (2025) ▸ Backing out $\hat{A}$ ▸ Marginal effects

$$\Delta y_{it} = \alpha_i + \beta_1 \Delta T_{it} + \beta_2 \Delta T_{it} T_i^{50-80} + \varepsilon_{it}$$

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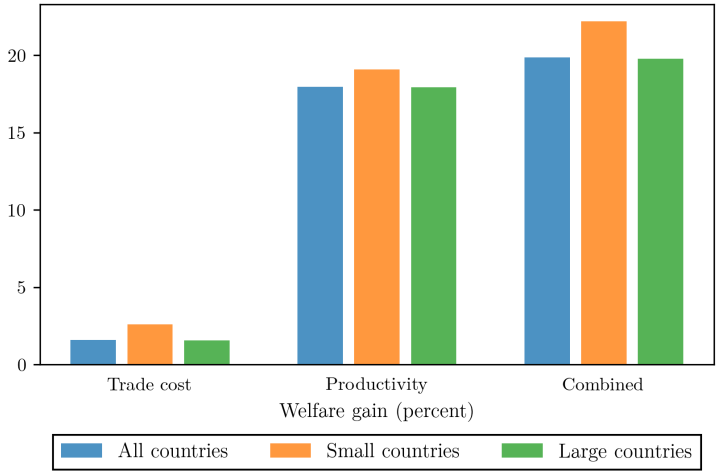
$$\Delta y_{it} = \alpha_i + \beta_1 \Delta T_{it} + \beta_2 \Delta T_{it} T_i^{50-80} + \varepsilon_{it}$$

- Compare welfare impacts of trade cost only, productivity only, both

Welfare gains across different scenarios



▸ Distribution of welfare differences

Conclusion

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- Ignoring this leads to ≈ 10 percent underestimate of welfare impact

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- Climate change increases trade cost
- Ignoring this leads to ≈ 10 percent underestimate of welfare impact
- Methodology easy to use with any model that yields gravity equation

Thank you!

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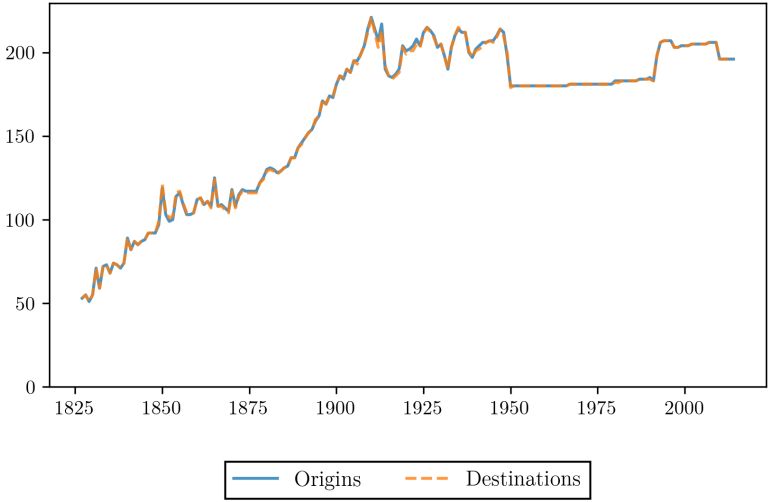
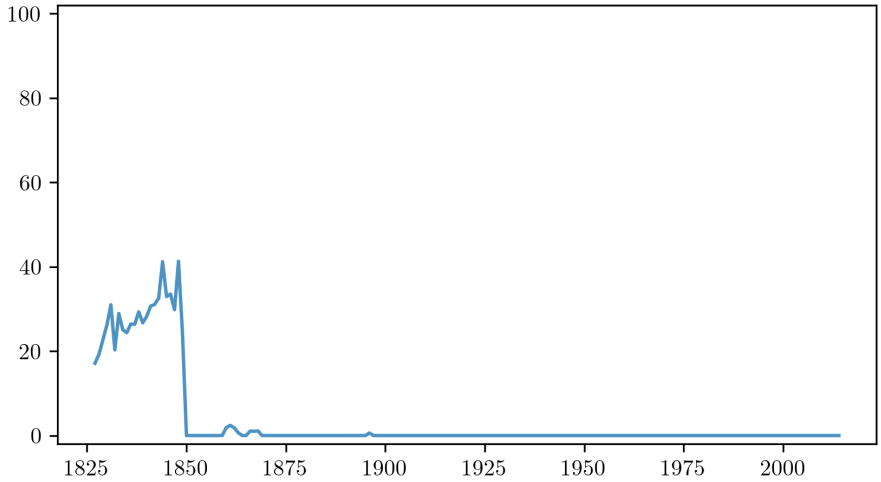
Trade data country counts by year



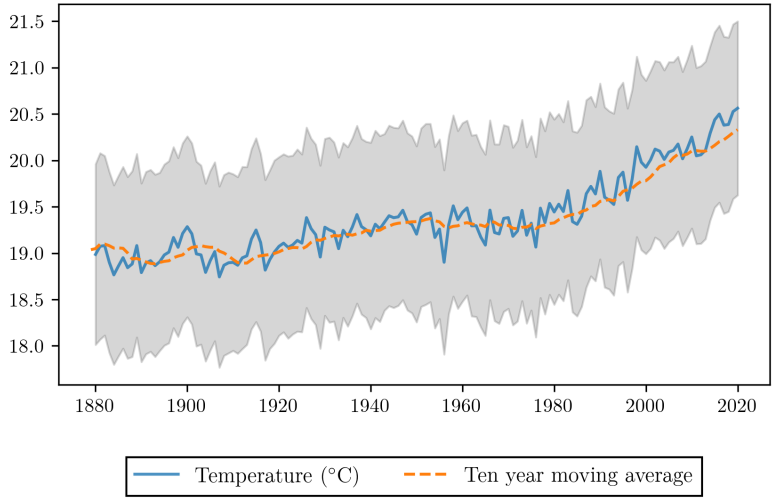
Flow counts Back

Unmatched trade flows (percent) by year



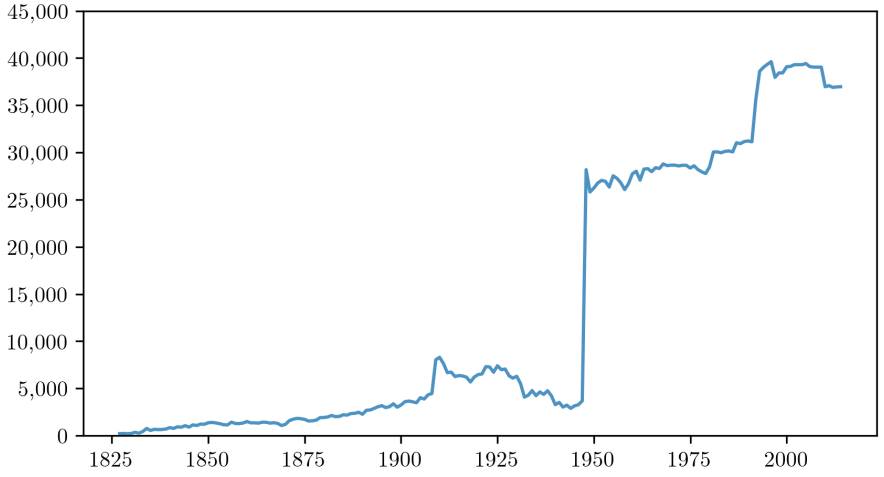
Observation counts Back

Average temperature (°C) by year



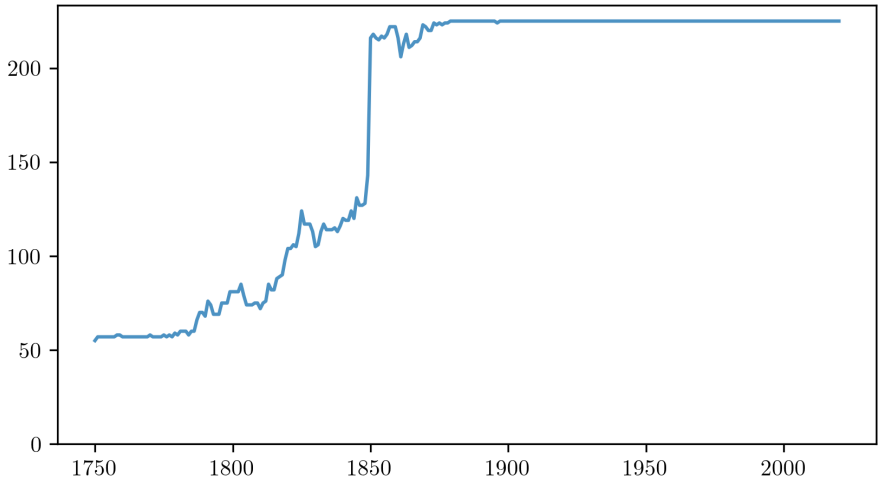
Back

Trade flow counts by year



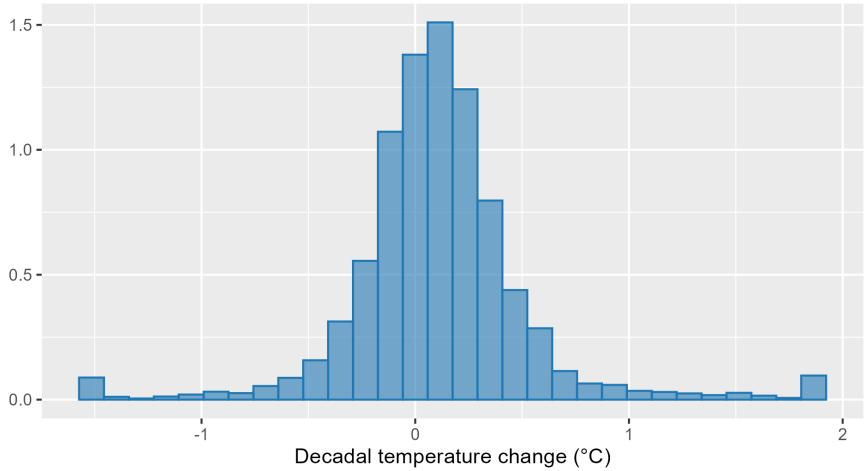
Back

Weather observation counts for current countries by year



Back

Decadal temperature changes



Back

Gravity estimation results

Variable	Basic model	$T_{50\text{-}'80}$ deciles	$T_{50\text{-}'80}$ deciles & time trend	CC deciles	CC deciles & time trend	Lat. deciles	Lat. deciles & time trend	Weighted distance	Drop CHN	Decade $\geq$ '50s	Full interaction	Residual T	Benchmark
$\tilde{d}_{ni} \times 2010s$	−0.552 [0.000]	−0.899 [0.000]	−0.903 [0.000]	−0.744 [0.000]	−0.791 [0.000]	−0.663 [0.000]	−0.974 [0.000]	−0.590 [0.000]	−0.548 [0.000]	−0.620 [0.000]	−0.552 [0.000]	−0.581 [0.000]	−0.565 [0.000]
$\tilde{d}_{ni} \times \Delta T_{it}$	−0.095 [0.000]	−0.125 [0.000]	−0.134 [0.000]	−0.048 [0.031]	−0.053 [0.010]	−0.156 [0.000]	−0.192 [0.000]	−0.137 [0.000]	−0.122 [0.000]	−0.096 [0.001]	−0.099 [0.000]	−0.204 [0.000]	
$\tilde{d}_{ni} \times \Delta T_{nt}$	−0.066 [0.011]	−0.089 [0.000]	−0.090 [0.000]	−0.038 [0.081]	−0.014 [0.485]	−0.116 [0.000]	−0.123 [0.000]	−0.098 [0.000]	−0.090 [0.004]	−0.069 [0.011]	−0.070 [0.017]	−0.199 [0.000]	
$\tilde{d}_{ni} \otimes$ decade	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\tilde{d}_{ni} \otimes T_{50\text{-}'80}$ decile$_i$	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes T_{50\text{-}'80}$ decile$_n$	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes T_{50\text{-}'80}$ decile$_i \times$ decade	No	No	Yes	No	No	No	No	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes T_{50\text{-}'80}$ decile$_n \times$ decade	No	No	Yes	No	No	No	No	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes$ CC decile$_i$	No	No	No	Yes	Yes	No	No	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes$ CC decile$_n$	No	No	No	Yes	Yes	No	No	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes$ CC decile$_i \times$ decade	No	No	No	No	Yes	No	No	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes$ CC decile$_n \times$ decade	No	No	No	No	Yes	No	No	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes$ Lat. decile$_i$	No	No	No	No	No	Yes	Yes	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes$ Lat. decile$_n$	No	No	No	No	No	Yes	Yes	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes$ Lat. decile$_i \times$ decade	No	No	No	No	No	No	Yes	No	No	No	No	No	No
$\tilde{d}_{ni} \otimes$ Lat. decile$_n \times$ decade	No	No	No	No	No	No	Yes	No	No	No	No	No	No
$\mathbf{C}_{ni} \otimes$ decade	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Origin-decade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Destination-decade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	326,747	326,747	326,747	326,747	326,747	326,747	326,747	293,461	237,391	323,031	326,747	324,433	327,550
Clusters	28,993	28,993	28,993	28,993	28,993	28,993	28,993	22,118	23,078	23,078	28,993	28,943	28,993

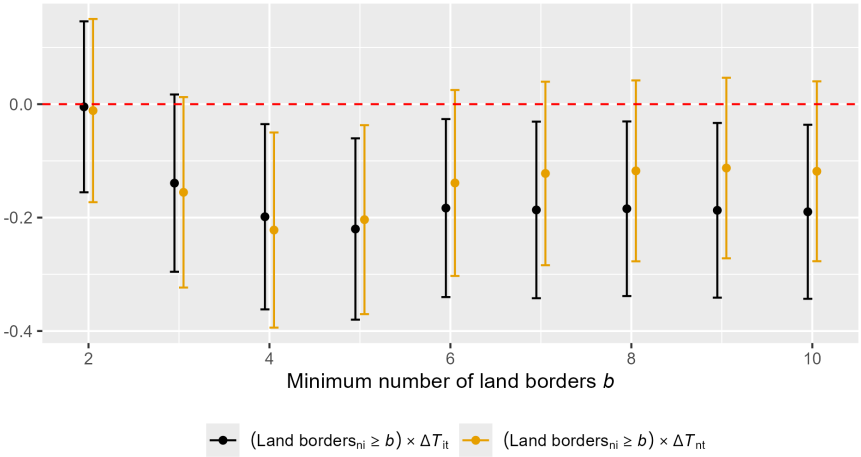
◂ Back

Mechanisms behind main results

Variable	Sea only trade	Long distance trade
Sea only$_{ni}$ × 2010s	−0.564 [0.000]	
Sea only$_{ni}$ × ΔT_{it}	−0.165 [0.004]	
Sea only$_{ni}$ × ΔT_{nt}	−0.036 [0.507]	
Long distance$_{ni}$ × 2010s		−0.443 [0.000]
Long distance$_{ni}$ × ΔT_{it}		−0.101 [0.107]
Long distance$_{ni}$ × ΔT_{nt}		−0.028 [0.626]
Sea only$_{ni}$ ⊗ decade	Yes	No
Long distance$_{ni}$ ⊗ decade	No	Yes
$\mathbf{C}_{nit}$ ⊗ decade	Yes	Yes
Origin-decade FE	Yes	Yes
Destination-decade FE	Yes	Yes
Observations	326,747	326,747
Clusters	28,993	28,993

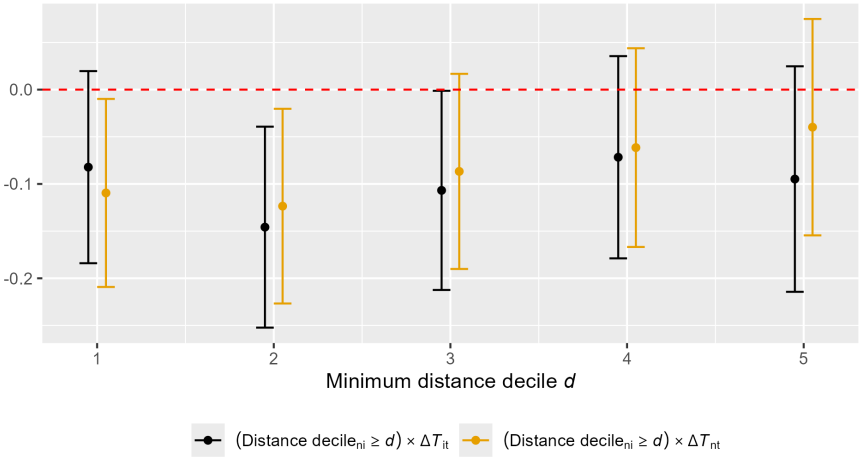
◂ Back

Land border crossing donut hole estimation



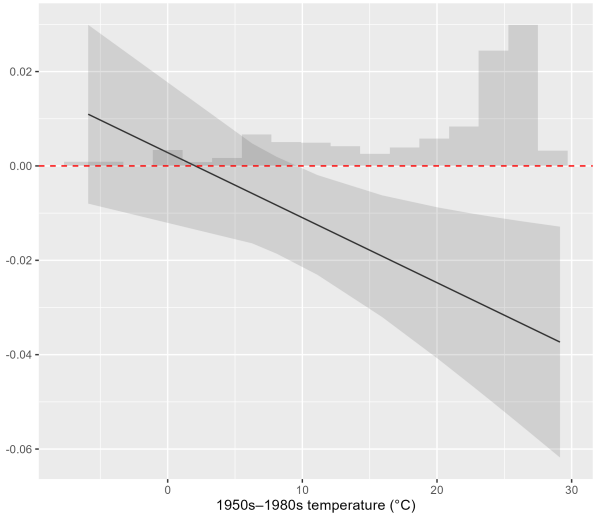
Back

Distance decile donut hole estimation



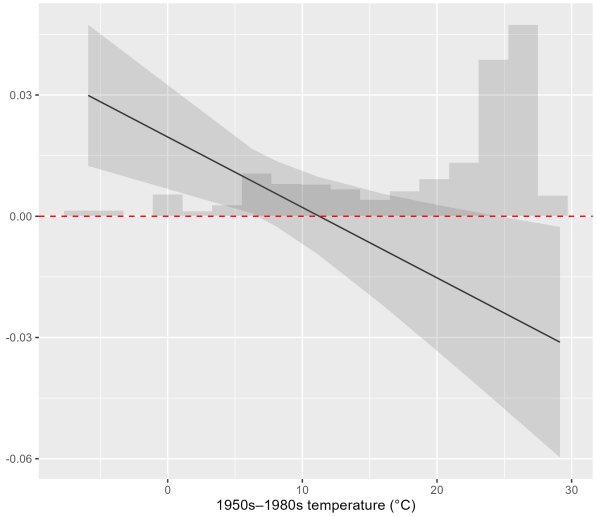
Back

UNCTAD container port throughput



Back

UNCTAD container port throughput, controlling for Δy



Back

Adaptation

- Impact especially clear in

Back

Adaptation

- Impact especially clear in
  - Colder countries (1950–1980 average T) ▸ Plot

◂ Back

Adaptation

- Impact especially clear in
  - Colder countries (1950–1980 average T) ▸ Plot
  - Countries with faster climate change (1900s–2000s ΔT) ▸ Plot

◂ Back

Adaptation

- Impact especially clear in
  - Colder countries (1950–1980 average T) Plot
  - Countries with faster climate change (1900s–2000s ΔT) Plot
- Countries seem adapted to long term environment ...

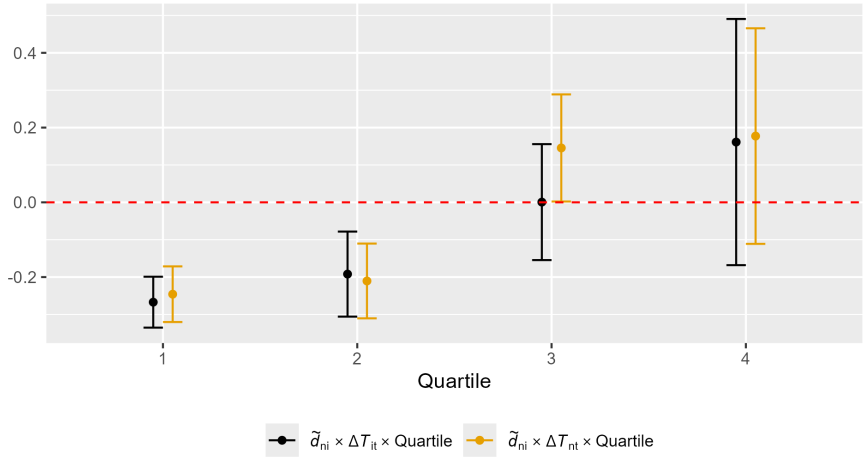
Back

Adaptation

- Impact especially clear in
  - Colder countries (1950–1980 average T) Plot
  - Countries with faster climate change (1900s–2000s ΔT) Plot
- Countries seem adapted to long term environment . . .
- . . . but cannot adapt to fast change

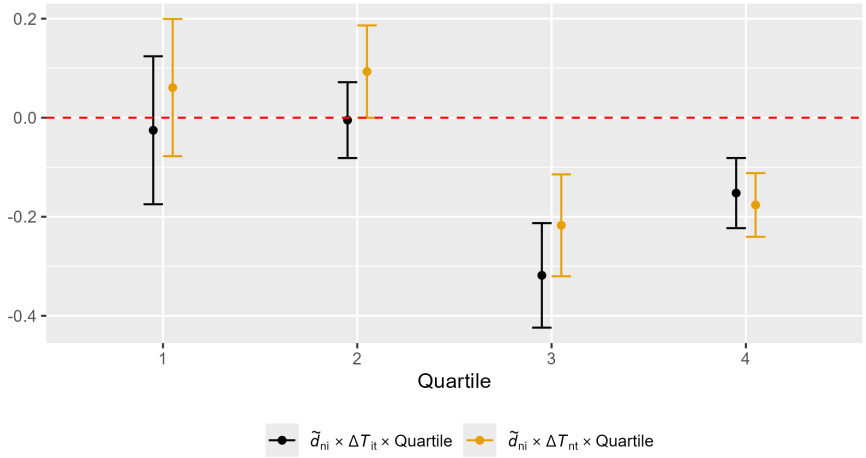
Back

Effect across 1950–1980 average temperature quartiles



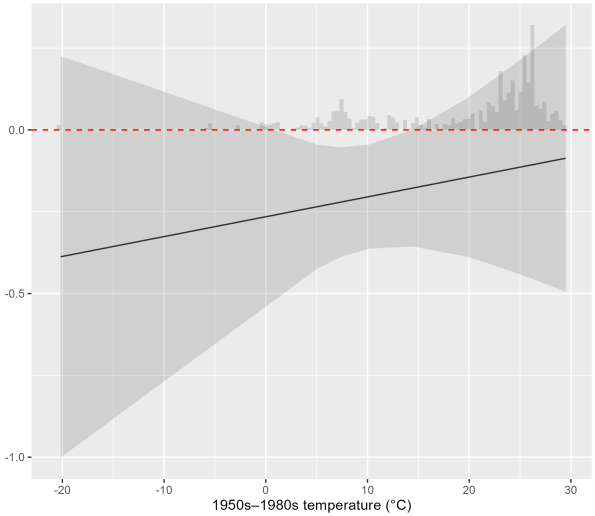
Back

Effect across 1900s–2000s climate change quartiles



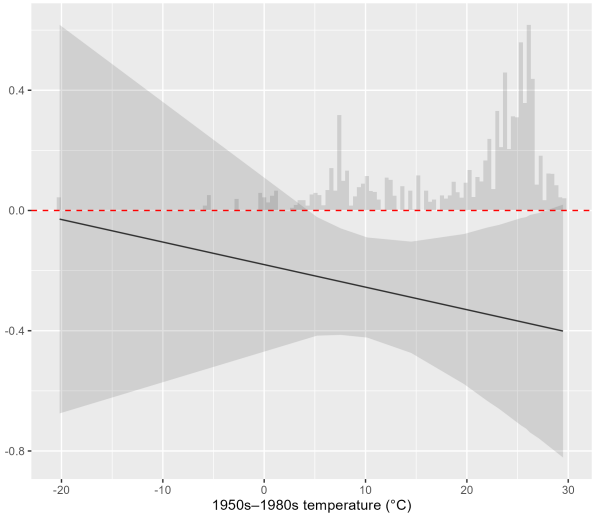
Back

Marginal effect of temperature on trade cost — origin



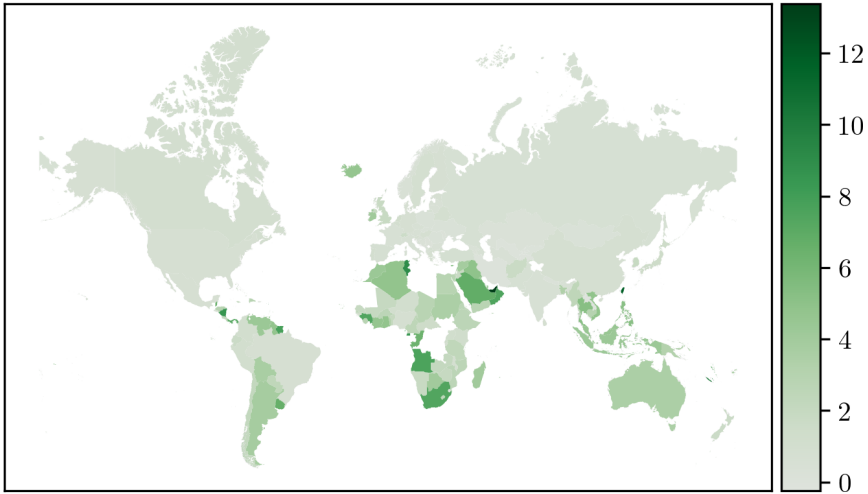
Back

Marginal effect of temperature on trade cost — destination



Back

Welfare change (1910s) across countries



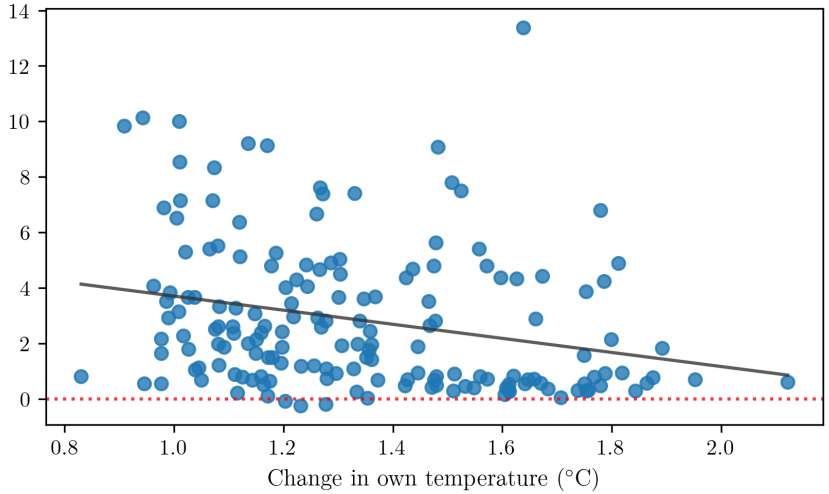
Back

Correlates of welfare changes

Variable	$\hat{W}_{it}$	$\hat{W}_{it}$	$\hat{W}_{it}$
Own ΔT	-1.661 [0.000]		-0.111 [0.873]
Inverse distance weighted ΔT		-4.729 [0.000]	-4.512 [0.007]
Decade FE	Yes	Yes	Yes

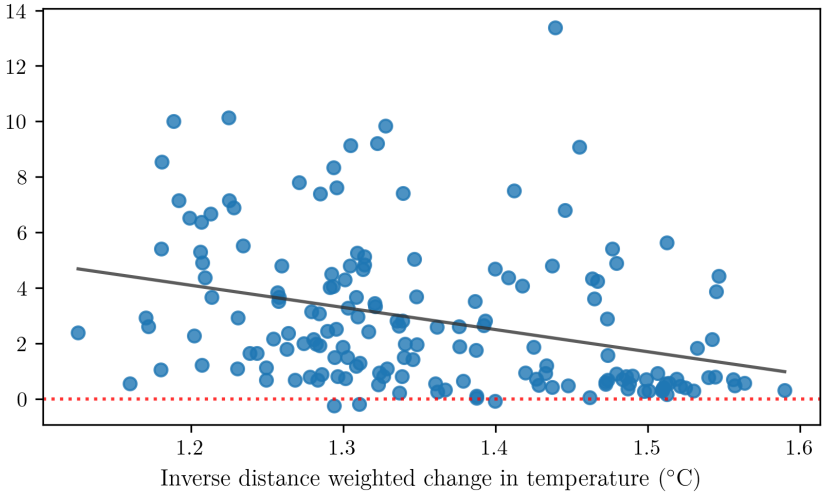
▸ Temperature scatterplots ▸ GDP scatterplots ▸ Full table ◂ Back

Welfare change across own temperature change



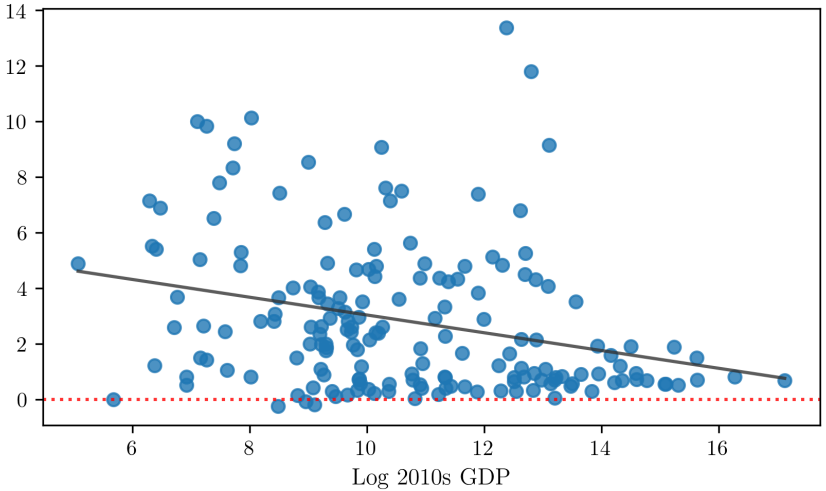
Back

Welfare change across neighbors' temperature change



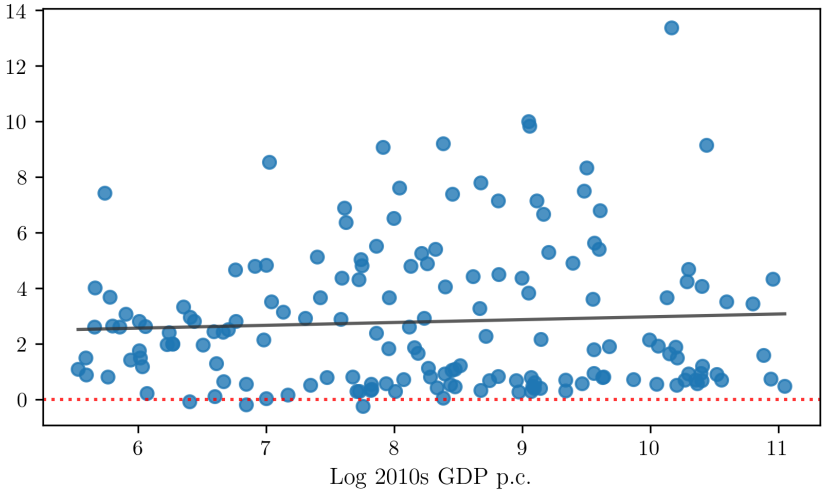
Back

Welfare change across 2010s GDP



Back

Welfare change across 2010s GDP per capita



Back

Additional correlates of welfare changes

Variable	$\hat{W}_{it}$	$\hat{W}_{it}$	$\hat{W}_{it}$	$\hat{W}_{it}$	$\hat{W}_{it}$	$\hat{W}_{it}$
Log 2010s GDP				−0.233 [0.000]	−0.219 [0.000]	0.112 [0.048]
Own ΔT	−1.661 [0.000]		−0.111 [0.873]		−0.034 [0.956]	
Inverse distance weighted ΔT		−4.729 [0.000]	−4.512 [0.007]		−3.348 [0.030]	
2010s own trade share (%)						−0.060 [0.000]
Decade FE	Yes	Yes	Yes	Yes	Yes	Yes

Back

Backing out $\hat{A}$

- GDP per capita (real wages) are

$$y_{it} \equiv \frac{w_{it}}{\mathcal{P}_{it}} = \Gamma \left(\frac{\theta - \sigma + 1}{\theta} \right)^{\frac{1}{\sigma - 1}} \left(\frac{A_{it}}{\pi_{iit}} \right)^{\frac{1}{\theta}}$$

- Under autarky ($d_{nit} \to +\infty \, \forall \, i, n \neq i$), $\pi_{iit} \to 1$, so

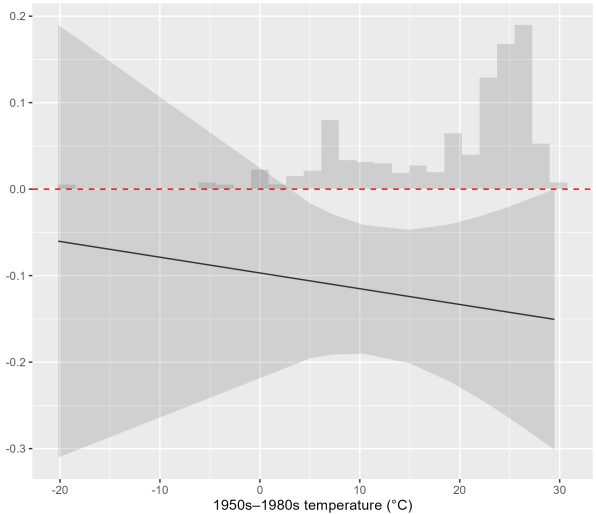
$$\hat{y}_{it} = \hat{A}_{it}^{\frac{1}{\theta}}$$

- Reduced form estimates $\log(\hat{y}_{it})$, can back out

$$\hat{A}_{it} = \exp\{\theta \log(\hat{y}_{it})\}$$

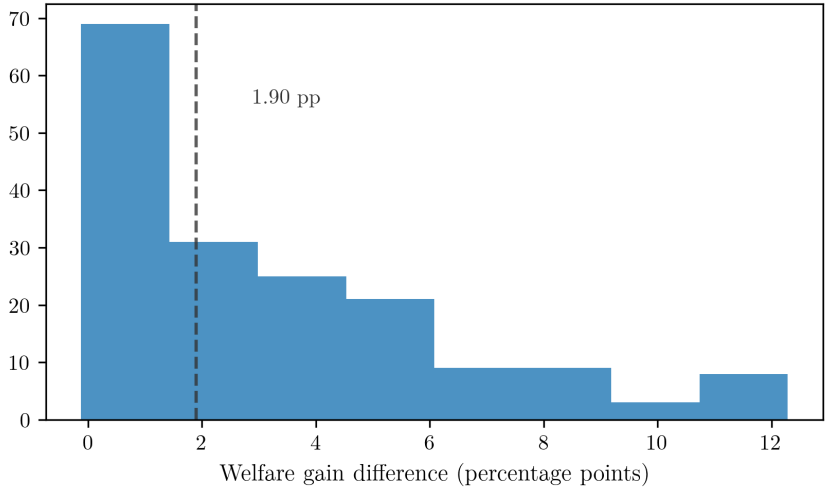
◂ Back

Marginal effect of temperature on productivity



Back

Additional welfare gains



Back