

Heterogeneous effects of weather shocks on firm economic performance

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Overview

Motivation

Why Damages Heterogeneity

- Climate damages mostly estimated at aggregate level (top-down)
- Within-country climate damages heterogeneity mostly neglected
- Accounting for **granular damages heterogeneity** is crucial for
 - **Economics**: average marginal effects can mask heterogeneous impacts
 - **Policy**: identifying **winners** and **losers** allows to design **tailored** mitigation and adaptation policies

Research Question

Are climate damages heterogeneous across firms?

This paper explores the economic impacts of increasing temperatures on firms' economic performance across firms characteristics.

Firm-level Literature and Contribution

Literature:

- Effects of weather shocks on firms' outcomes: Zhang et al. (2018), Chen and Yang (2019), Addoum et al. (2020), Nath (2020), Ponticelli et al. (2023), Caggese et al. (2023)

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Contribution:

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Contribution:

- First paper to focus on European firms (Europe is an ideal setting)
- Include non-listed firms and SME
- Estimate firms' characteristics heterogeneity in climate damages: TFP-category (today), Industry and size (in the paper)
- Estimate probability of weather-induced firm exit (today)

Overall Contribution

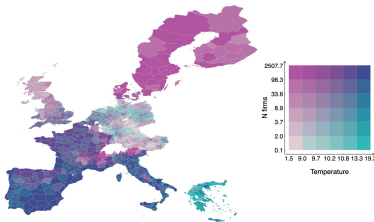
This paper contributes to four strands of literature:

- **Climate Economics:** identifies sources of heterogeneity in climate damages
- **Climate Econometrics:** addresses methodological issues highlighted in the literature (model selection, nonstationarity)
- **Aggregate Productivity:** discusses economy-wide effects of climate damages heterogeneity in firms productivity levels (convergence, firm inequality, aggregate productivity slow-down)
- **Firm Dynamics:** estimates effects of rising temperatures on firms' exit probability

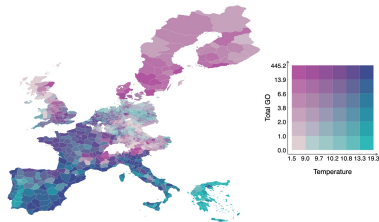
Data and Identification Strategy

Data

- BvD Orbis Historical, 1995-2020 yearly data, coverage varies by country
Coverage
- Merged with Copernicus ERA5-Land data (0.1° grid ~ 9 km)
- Inverse-distance weighting matching



(a) Temperature and N firms



(b) Temperature and tot GO

Figure: Bivariate spatial distributions, values aggregated at the Nuts 3-level

Empirical Strategy I

FEs Distributed Lag Model: Identification issues

1. **Nonstationarity:** Panel unit-root Augmented Dickey Fueller tests
2. **Identification:** T-bins VS yearly average temperature discussion
3. **Model specification:** CV and IC to select optimal model

Details

Empirical Strategy II

FEs Distributed Lag Model: 2nd order polynomial

$$\Delta y_{i,t} = \alpha + \beta_0 T_{i,t} + \gamma_0 T_{i,t}^2 + \sum_{\ell \geq 1} \beta_{\ell} T_{i,t-\ell} + \sum_{\ell \geq 1} \gamma_{\ell} T_{i,t-\ell}^2 + \zeta_0 P_{i,t} + \zeta_1 P_{i,t}^2 + \delta_i + \lambda_{c,n,t} + \varepsilon_{i,t}$$

- $y_{i,t}$ = log of firm i's GO, VA, TFP, L, K, M in year t
- $T_{i,t}$ = yearly average temperature for firm i in year t
- $P_{i,t}$ = yearly total precipitation for firm i in year t
- δ_i = firm fixed effects
- $\lambda_{c,n,t}$ = country-industry-year fixed effects
- $\varepsilon_{i,t}$ = autocorrelated and spatially correlated errors (SE clustered at Nuts 3 province level)

Identification assumption (strict exogeneity)

$$\mathbb{E}[\varepsilon_{i,t} \mid g(T_{i,t}), f(P_{i,t}), \{h(T_{i,t-1}), \dots, h(T_{i,t-L})\}, \delta_i, \lambda_{c,n,t}] = 0 \quad \forall \quad t = 1, \dots, T$$

Overview
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Data and Identification
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Results
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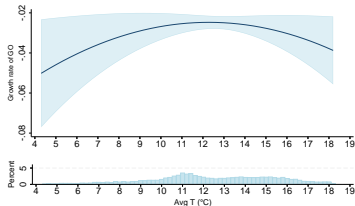
Conclusions
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Appendix
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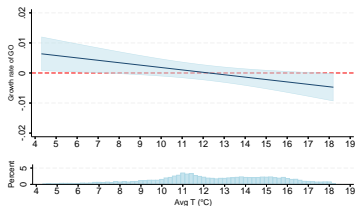
Results

Not Significant Contemporaneous Effect

- Inverted-U-shaped relationship
 - Contemporaneous ($T_{i,t}$) marginal effect statistically and economically not significant
- Lags Country-level



(a) 2nd order polynomial prediction



(b) 2nd order polynomial marginal effect

Figure: Contemporaneous Prediction (a) and marginal effect (b) of temperature on the growth rate of gross output. Point estimates and 95% CI reported. Y-axis refers to change in percentage points.

Marginal Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	ΔGO	ΔVA	ΔTFP	ΔL	ΔK	ΔM
T	0.0098** (0.0042)	0.0043 (0.0037)	0.0015 (0.0029)	0.00063 (0.0027)	0.0096*** (0.0027)	0.0015 (0.0030)
T^2	-0.00040** (0.00016)	-0.00024 (0.00015)	-0.00013 (0.00011)	-0.000066 (0.00012)	-0.00035*** (0.00011)	-0.00011 (0.00012)
$(\ell 1)T$	0.00078 (0.0051)	-0.0056 (0.0048)	-0.0029 (0.0045)	-0.0088*** (0.0024)	0.0097*** (0.0032)	-0.0049 (0.0040)
$(\ell 1)T^2$	-0.00011 (0.00021)	0.000031 (0.00020)	0.000033 (0.00018)	0.00011 (0.00011)	-0.00034*** (0.00012)	0.00012 (0.00016)
$(\ell 2)T$	0.0047 (0.0042)	0.0012 (0.0045)	-0.00090 (0.0046)	0.0011 (0.0023)	0.011*** (0.0032)	0.0049* (0.0029)
$(\ell 2)T^2$	-0.00023 (0.00020)	-0.000099 (0.00021)	-0.0000044 (0.00020)	-0.000024 (0.00010)	-0.00037*** (0.00013)	-0.00015 (0.00014)
<i>Constant</i>	-0.087 (0.073)	0.063 (0.068)	0.052 (0.060)	0.091** (0.037)	-0.17*** (0.052)	0.013 (0.052)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Cou-Ind-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.16	0.14	0.12	0.14	0.15	0.15
N	43,010,224	32,189,101	18,442,532	25,570,937	38,146,624	31,095,285

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table: Point estimates and standard errors from the regressions of weather variables on the growth rates of relevant variables (P and P^2 not reported for presentational reasons).

Not Significant Pooled Results

What is driving not significant marginal effects?

- Europe is not affected by weather shocks
- European firms have already adapted to warmer climate
- **Heterogeneous effects averaged out in not significant results**

TFP-Category Heterogeneity

Economic Performance

- TFP categories defined over the first 2 available years
- Upward-sloping marginal effect for more productive firms
- Downward-sloping marginal effect for less productive firms

Lags

Inputs

Country-level

Cat. by industry

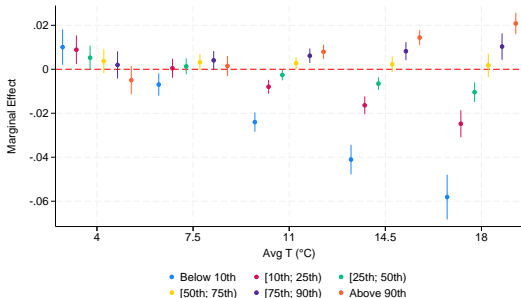
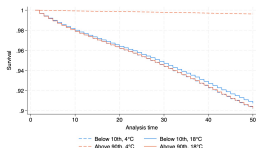


Figure: Marginal effect of yearly average temperature on gross output (growth rates) by firm TFP category (95% confidence intervals). Y-axis refers to change in percentage points.

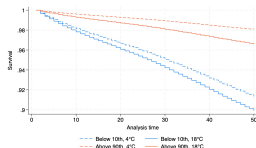
TFP-Category Heterogeneity

Firm Dynamics

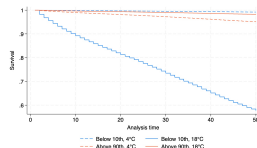
- Survival functions for high and low-productive firms in cold and warm areas



(a) Contemporaneous



(b) Lag 1



(c) Lag 2

Figure: Estimated survival functions $S(T)$ for the least-productive (bottom productivity decile) and the most-productive (top productivity decile) firms located in cold ($4^{\circ}C$) and warm ($18^{\circ}C$) areas.

Conclusions

Conclusions

- Inverted-U-shaped relationship between temperatures and economic performance in pooled analysis - effect mostly insignificant
- Damages heterogeneity identifies winners and losers:
 - Across Countries
 - **Across firm TFP categories** (relevant source of climate damages heterogeneity)
 - Across industries
 - Across firm size categories

Thank you!

WP available on [SSRN](#) and [GRI](#)

For any comments:

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Appendix

Temperature Distribution

- Distribution of yearly average temperature across all firm-year observations [Back](#)

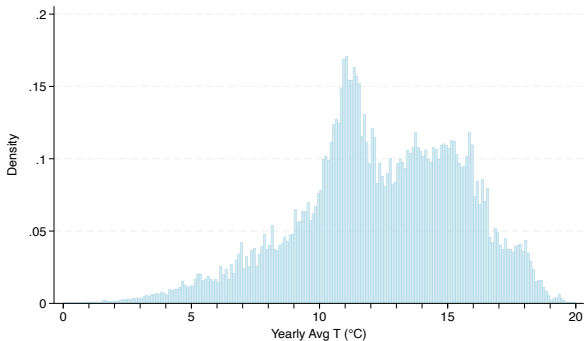


Figure: Temperature distribution

Data Coverage

- Orbis coverage by country and year, calculated as a share between total GO of firms in Orbis and total gross output in EUROSTAT [Back](#)

$$Coverage_{c,t} = \frac{\sum_{i \in C} GO_{i,t}}{\sum_{r \in C} GO_{r,t}}$$

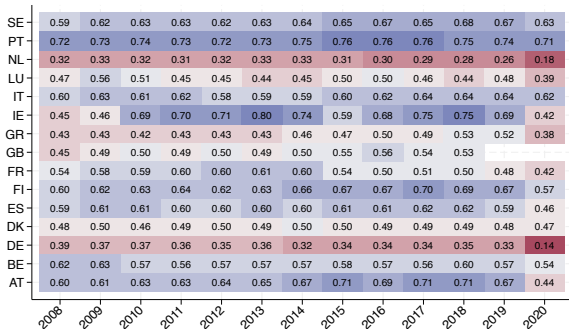


Figure: Coverage of the Orbis dataset across Country and years

Data by Industry (Nace2 Rev. 2)

- Number of observations by Nace2 revision 2 1-digit industry [Back](#)

NACE2 1-digit	2000	2010	2020
A-Agriculture forestry and fishing	25,129	58,787	54,194
B-Mining and quarrying	4,923	7,174	4,560
C-Manufacturing	233,167	383,233	265,411
D-Electricity gas steam and air conditioning supply	4,129	21,133	23,767
E-Water supply sewerage waste management	5,905	14,921	11,703
F-Construction	201,733	498,560	300,410
G-Wholesale and retail trade repair of motor vehicles	385,209	744,214	485,038
H-Transportation and storage	58,885	124,987	97,082
I-Accommodation and food service activities	75,343	208,508	148,328
J-Information and communication	75,570	146,280	119,609
K-Financial and insurance activities	44,500	104,811	85,355
L-Real estate activities	120,510	335,598	252,419
M-Professional scientific and technical activities	138,312	365,279	295,435
N-Administrative and support service activities	72,921	161,534	115,258
O-Public administration and defence	395	915	632
P-Education	12,856	45,652	39,987
Q-Human health and social work activities	20,826	89,015	85,058
R-Arts entertainment and recreation	20,474	54,947	48,940
S-Other service activities	34,817	79,179	47,122
T-Activities of households as employers	12,418	16,145	3,161
U-Activities of extraterritorial organisations and bodies	52	201	110

Table: Total number of observations by Industry (Nace2 Rev. 2). Source: Orbis.

Empirical Strategy II

FEs Distributed Lag Model: Identification issues

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- 1. Nonstationarity:** issue raised for temperature series
 - in this panel, large N and short T \rightarrow concern \downarrow (Greene 2003)
 - panel unit root tests (ADF) reject nonstationarity of temperature.
- 2. Identification:** T-bins VS **yearly average temperature**
 - T-bins: clear identification and interpretation, but under strong assumptions + does not account for differences in adaptation
 - **Yearly average temperature:** less assumptions and broadly used in macroeconomic models, but identification not as clear
- 3. Model specification:** literature generally relies on quadratic model with L lags
 - post-estimation Information Criteria and Machine Learning Cross-Validation suggest higher order polynomials and more lags
 - IC and CV do not converge, largest relative improvement (%) for 2nd order polynomial with 2 lags (elbow rule spirit) Result

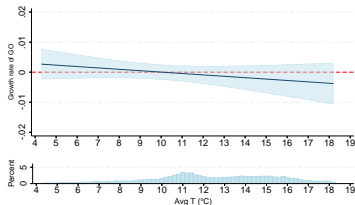
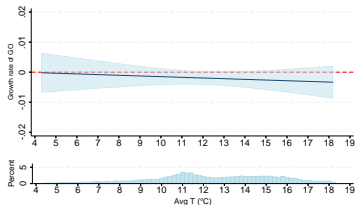
Identification: Post-estimation IC and ML CV

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	Information Criteria		Cross Validation	
	Akaike IC	Bayesian IC	Mean	SD
poly 1 lag 0	96,246,866	96,246,929	0.69358186	0.00074038
poly 1 lag 1	96,246,868	96,246,947	0.69357927	0.00074092
poly 1 lag 2	71,755,475	71,755,569	0.61942618	0.00058512
poly 1 lag 3	58,126,088	58,126,196	0.59742817	0.00040273
poly 1 lag 4	47,867,591	47,867,713	0.58367275	0.00049614
poly 1 lag 5	39,709,263	39,709,399	0.57427776	0.00036762
poly 2 lag 0	96,246,596	96,246,675	0.69363934	0.00074288
poly 2 lag 1	96,246,457	96,246,568	0.69376047	0.00074541
poly 2 lag 2	71,755,388	71,755,528	0.61936773	0.00058616
poly 2 lag 3	58,125,968	58,126,138	0.59734969	0.00040642
poly 2 lag 4	47,867,460	47,867,658	0.58355948	0.00050144
poly 2 lag 5	39,709,128	39,709,354	0.57423643	0.00037318
poly 3 lag 0	96,246,506	96,246,601	0.69363498	0.00074250
poly 3 lag 1	96,246,366	96,246,508	0.69373925	0.00074524
poly 3 lag 2	71,755,382	71,755,569	0.61936904	0.00058617
poly 3 lag 3	58,125,947	58,126,178	0.59731763	0.00040354
poly 3 lag 4	47,867,443	47,867,717	0.58345314	0.00050233
poly 3 lag 5	39,709,092	39,709,409	0.57393991	0.00036960
poly 4 lag 0	96,246,500	96,246,610	0.69364369	0.00074306
poly 4 lag 1	96,246,343	96,246,517	0.69378355	0.00074678
poly 4 lag 2	71,755,265	71,755,499	0.61936615	0.00058748
poly 4 lag 3	58,125,798	58,126,091	0.59735727	0.00040871
poly 4 lag 4	47,867,263	47,867,614	0.58356162	0.00050331
poly 4 lag 5	39,708,932	39,709,340	0.57405486	0.00037542

Lagged Damages

- Downward-sloping lagged marginal effects [Back](#)
- Economically and statistically insignificant estimates
- Evidence of persistent growth effect, though imprecisely estimated

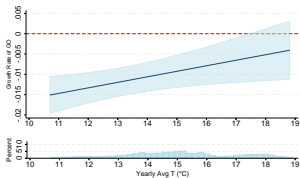


(a) 2nd order polynomial marginal effect of $T_{i,t-1}$ (b) 2nd order polynomial marginal effect of $T_{i,t-2}$

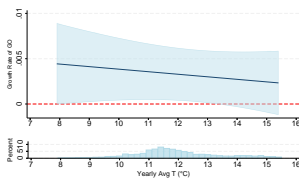
Figure: Marginal effect of temperature on the growth rate of gross output in $T_{i,t-1}$ and $T_{i,t-2}$. Point estimates and 95% CI reported

Aggregate Results by Country

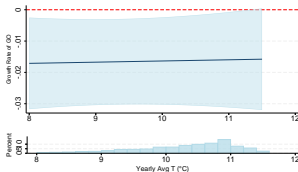
- Substantial cross-country heterogeneity [Back](#)
- Largest economies with good coverage are reported



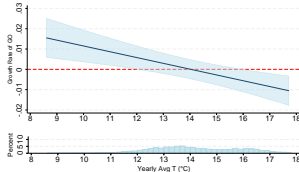
(a) Marginal Effect ES



(b) Marginal Effect FR

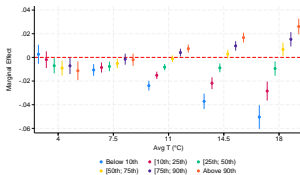


(c) Marginal Effect GB

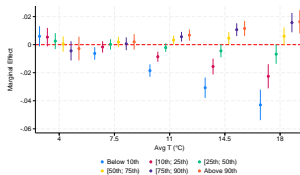


(d) Marginal Effect IT

Heterogeneity by Lags: TFP categories



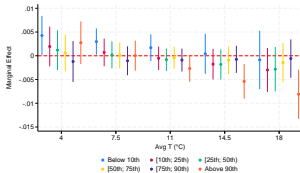
(a) 1-Lag Marginal Effect



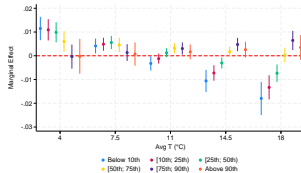
(b) 2-Lag Marginal Effect

Back

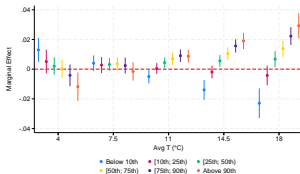
Heterogeneity by Production Factor: TFP categories



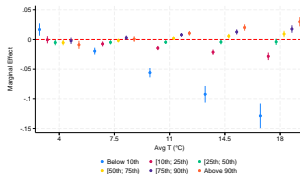
(a) Marginal Effect L



(b) Marginal Effect K



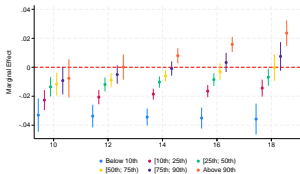
(c) Marginal Effect M



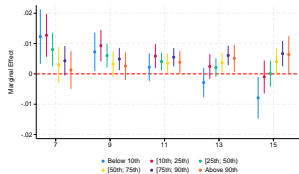
(d) Marginal Effect TFP

Heterogeneity by Country: TFP categories

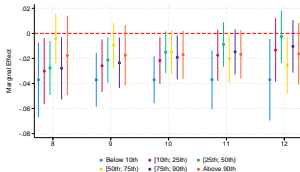
- Low productive firms consistently negatively impacted across countries
- High productive firms consistently positively or not impacted across countries



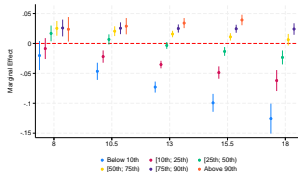
(a) Marginal Effect ES



(b) Marginal Effect FR



(c) Marginal Effect GB



(d) Marginal Effect IT

TFP-Category Heterogeneity

TFP-Categories by Industry

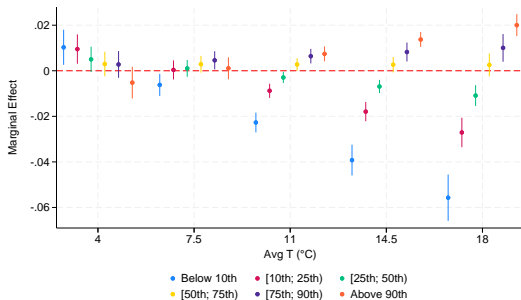


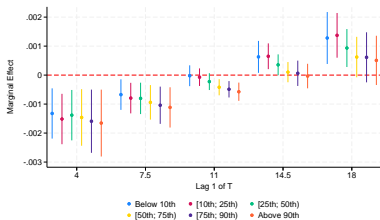
Figure: Marginal effect of yearly average temperature on gross output (growth rates) by firm TFP category (defined within each industry) (95% confidence intervals).

TFP-Category Heterogeneity

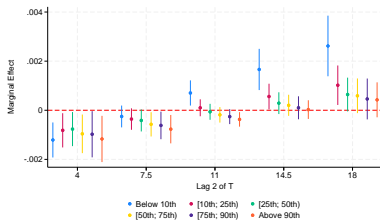
Firm Dynamics

- Marginal effects of higher temperature on firms' exit probability

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(a) Lag 1 - LPM



(b) Lag 2 - LPM

Figure: Estimated marginal effects of higher temperatures on firms' exit probability. Results from the Linear Probability Model (LPM)

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