Impact of Temperature on Banks' Loan Supply: Evidence from French Firms

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Outline

Background

The impact of climate change on corporates and banks, and the underlying transmission mechanisms to the economy and the financial system, remain underexplored.

- Literature has focused relatively more on acute physical risk (e.g. heat waves (Acharya et al., 2020), floods, droughts (Javadi & Masum, 2021)) than chronic risks (e.g. temperature & sea-level rises).
- Temperature rise affects firms' performance (Burke et al., 2015), but its impact on credit supply and pricing is less well understood (de Bandt et al., 2025).
- ECB (2020) guidance to include, both, acute, and chronic risk in the ICAAP (Basel framework, Pillar 2):

"Institutions are expected to consider climate-related and environmental risks at all relevant stages of the credit-granting process".

This Paper

This paper assesses the effects of rising temperatures on French firms and banks' loan portfolios.

Research question

• Does chronic temperature rise affect banks' credit supply, as measured by outstanding banks' loan growth ?

Approach

• Map granular firm-bank loans to temperature exposure.
• Adopt a difference-in-differences approach based on a robust methodology.

Contribution

• Quantify the impact of chronic temperature rise on banks' loan supply (measuring banks' perception).
• Disentangle heterogeneous effects by loan maturity, sectors, exposure length, and magnitude/severity of temperature rise exposure.

Main Findings

- Firms exposed to chronic temperature shifts experience lower loan growth compared to their non-exposed pairs
- Our results suggest that banks are expressing a cautious attitude towards exposed firms, as we control for demand effect at the sector level
- The effect is mainly driven by medium & long-term loans
- We observe several layers of heterogeneity (sectoral, loans' maturities, temperature thresholds)

The Dataset

Combines:

- National credit registry (SCR) at the firm-bank-month level (Banque de France)
- BIC-IS fiscal data at the firm-year level (Fiscal Authorities)
- Meteo-France weather data at the station-month level (Météo-France)
- Geolocation data at the establishment level (INSEE)

Sample Selection Criteria

- Investigation period: 2010–2023.
- We keep only single-establishment firms which enable accurate exposure mapping.
- Exclude:
    - Financial, public administrations and agriculture sectors
    - Firms under simplified fiscal regimes
    - Fiscal declarations for operating activity longer than 14 months
- Winsorization at 2.5th 97.5th percentiles of the financial data.

→ **Final sample: Over 2.5 million observations, 600,000 firm-bank pairs and 290,000 firms and 500 banks.**

Key Temperature Concepts

Heatwaves

No single definition, but common features:

- Indicators: may include **day** and **night** high temperatures (and humidity) for a minimum duration.
- Duration : generally, at least 2–5 **consecutive** days with daily temperatures exceeding a certain threshold.
- Thresholds: vary by **region** and context (e.g. Greater London 28°C[1] , Greece 39°C[2], California 37.8°C, Australia 40°C[3].

→ Heatwaves have received increasing attention in recent years in the economic literature (e.g. Addoum et al., 2021;2023; Acharya et al., 2020 amongst others).

[1] The Met Office – www.metoffice.gov.uk

[2] Hellenic National Meteorological Service

[3] Australian Bureau of Meteorology – www.bom.gov.au

Key Temperature Concepts

Chronic Temperature Rise

- Long-term shifts in average temperatures.
- More relevant for assessing chronic physical climate risks.
- Can be measured by annual temperatures change or deviation from a reference period average.

→ In contrast, chronic temperature rise, which includes, both, acute, and less salient events, is relatively less frequently studied at the granular level in the literature.

In our investigation, we will focus on the impact chronic temperature rise on banks' loan supply, as measured by outstanding loans' growth.

To identify key drivers and for robustness, we also consider acute temperature thresholds.

We proxied chronic temperature shifts by the annual average of monthly maximum temperatures (TX), which captures firms' actual daytime exposure.

Treatment Definition

Excess heat exposure: is the deviation of TX average for a given year from the 1976-2005 TX realizations defined as :

$$\mathbb{1}\{\text{Excess Heat}_{it}^{TX_{Q_{th}}}\} \quad = \quad (TX_{it}^{Q_{th}} - TX_{i,1976-2005}^{Q_{th}}) > 0$$

- Reference period: 1976–2005 (Meteo-France baseline)[4].
- Other temperature indicators are also considered: $\sum_{d \in t} Days_{it} > 25°C$, 30°C and 35°C.

Once a firm is exposed (crosses heat threshold), it stays treated (absorbing state).

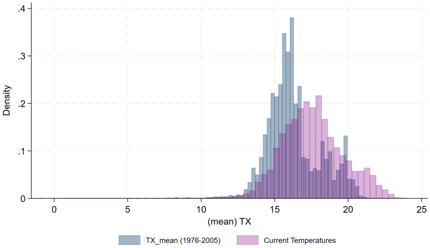
This *Staggered* design reflects:

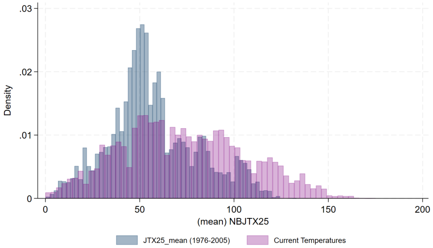
- Upward climate trends (unlikely to reverse in the foreseeable future).
- Forward-looking bank perception of risk, (once a risk is realized, it may occur again)

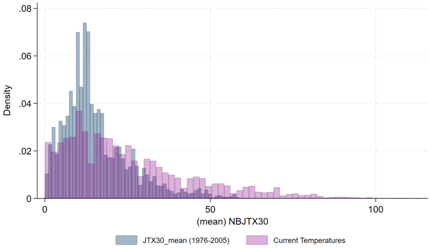
[4] Météo-France, Rapport DRIAS, 2020

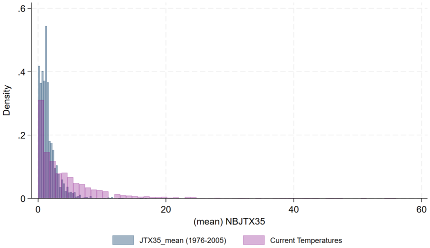
Sample Annual Temperature Realizations *vs* 1976–2005

Distribution of TX, > 25°C, 30°C and 35°C









Key Questions

Q1. Do firms exposed to excessive heat experience **lower credit growth**?

Q2. Do banks **adjust dynamically** to treatment patterns?

Q3. Is there **heterogeneity** across maturities and industries?

Empirical Design

Static TWFE specification

$$Y_{ibt} = \alpha_{ib} + \gamma_t + \beta \; ExcessHeat_{it}^{Q_{th}} + \psi \; \mathbf{X'}_{it} + \epsilon_{ibt} \tag{1}$$

- Y_{ibt}: is our outcome of interest for firm i at bank b in year t
  → We investigate two outcomes: Loans (log), and Loans growth (Δlog)
- α_{ib} and γ_t: firm-bank and year fixed effects, respectively
- X'_{it}: a set of controls vector (firm size, age, sector)
- ϵ_{ibt}: error term

Empirical Design

Event-Study specification (de Chaisemartin & D'Haultfœuille, 2023)

$$\delta_{g,\ell} = \mathbb{E}\left[Y_{g,t}(1) - Y_{g,t}(0) \mid D\right] \tag{2}$$

- $\delta_{g,\ell}$ is the average treatment effect for group g at time t after ℓ periods of treatment.
- D is the treatment indicator (1 if exposed to excessive heat, 0 otherwise).
- $\mathrm{Y}_{g,t}(1)$ and $\mathrm{Y}_{g,t}(0)$ are the potential outcomes for group g at time t

$$\delta_{\ell} = \sum_{(g,t)\in\mathcal{G}_{\ell}} \omega_{g,t}(\ell)\, \delta_{g,\ell} \tag{3}$$

- $\mathcal{G}_{\ell}$ is the set of groups that have been treated for ℓ periods.
- $\omega_{g,t}(\ell)$ are weights satisfying $\sum_{(g,t)\in\mathcal{G}_{\ell}} \omega_{g,t}(\ell) = 1$.

Results: Static TWFE

Table 1: Impact of Δ Average TX on Outstanding Loans Stock

	Dependent variable: Loans' Stock *(log)*								
	Panel A: All Maturities			**Panel B: Medium & Long-term**			**Panel C: Short-Term**		
	(1A)	(2A)	(3A)	(1B)	(2B)	(3B)	(1C)	(2C)	(3C)
$ExcessHeat_{it}^{TX_{0.90}}$	0.0244***			-0.0212***			0.0564***		
	(0.00247)			(0.00363)			(0.00755)		
$ExcessHeat_{it}^{TX_{0.75}}$		0.0477***			0.00659			0.0374***	
		(0.00280)			(0.00414)			(0.00843)	
$ExcessHeat_{it}^{TX_{Avrg}}$			0.0756***			0.0406***			0.00505
			(0.00355)			(0.00526)			(0.0109)
FEs & Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	.7720946	.7721335	.7721573	.7296083	.7295963	.7296129	.6250713	.6250433	.6250308
Panels	471,110	471,110	471,110	301,384	301,384	301,384	223,095	223,095	223,095
Observations	2,405,268	2,405,268	2,405,268	1,604,064	1,604,064	1,604,064	1,006,470	1,006,470	1,006,470

Standard errors in parentheses
Omitted: SMEs - Age >= 10 years - Water and Electricity Distribution
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

- Effects are positive on total outstanding loans.
- A more nuanced picture emerges when considering the impact of temperature on different loan maturities and exposure severity.

Results: Static TWFE

Table 2: Impact of Days>30°C on Outstanding Loans Stock

	Dependent variable: Loans' Stock *(log)*								
	Panel G: All Maturities			Panel H: Medium & Long-term			Panel I: Short-Term		
	(1G)	(2G)	(3G)	(1H)	(2H)	(3H)	(1I)	(2I)	(3I)
$ExcessHeat_{it}^{Days_{0.90}^{\geq 30°C}}$	-0.00265			-0.0354***			0.0316***		
	(0.00238)			(0.00351)			(0.00712)		
$ExcessHeat_{it}^{Days_{0.75}^{\geq 30°C}}$		0.00477			-0.0335***			0.0341***	
		(0.00256)			(0.00379)			(0.00729)	
$ExcessHeat_{it}^{Days_{Avrg}^{\geq 30°C}}$			0.0221***			-0.0272***			0.0583***
			(0.00301)			(0.00444)			(0.00883)
FEs & Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	.7720707	.7720714	.7720850	.7296424	.7296321	.7296110	.6250471	.6250478	.6250627
Panels	471,110	471,110	471,110	301,384	301,384	301,384	223,095	223,095	223,095
Observations	2,405,268	2,405,268	2,405,268	1,604,064	1,604,064	1,604,064	1,006,470	1,006,470	1,006,470

Standard errors in parentheses
Omitted: SMEs – Age ≥ 10 years – Water and Electricity Distribution
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

- The impact of temperature is more pronounced for higher magnitudes and severities.
- Overlooking loans maturity heterogeneity could be misleading when evaluating the overall impact *Substitution effect*.

Results: Static TWFE

Table 3: Impact of Δ Average TX on **Loans Growth**

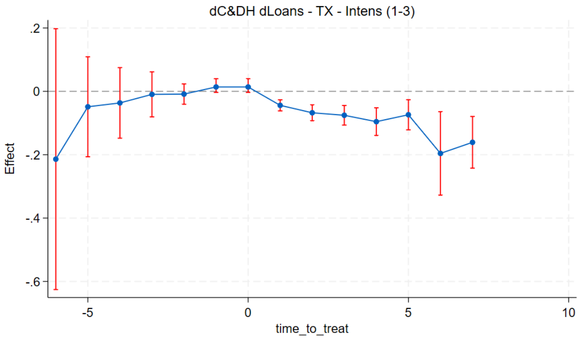
	Dependent variable: Loans' Growth (Δ *log*)								
	Panel L: All Maturities			**Panel K: Medium & Long-term**			**Panel L: Short-Term**		
	(1L)	(2L)	(3L)	(1K)	(2K)	(3K)	(1L)	(2L)	(3L)
$ExcessHeat_{it}^{TX_{0.90}}$	-0.0578***			-0.0643***			-0.00880		
	(0.00233)			(0.00360)			(0.00951)		
$ExcessHeat_{it}^{TX_{0.75}}$		-0.0790***			-0.0796***			-0.0499***	
		(0.00331)			(0.00510)			(0.0142)	
$ExcessHeat_{it}^{TX_{Avrg}}$			-0.0621***			-0.0689***			-0.142***
			(0.00534)			(0.00864)			(0.0285)
FEs & Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	.0368899	.0368124	.0364567	.0301923	.0300799	.0299024	.0366496	.0366496	.0366817
Panels	352,478	352,478	352,478	235,992	235,992	235,992	137,772	137,772	137,772
Observations	1,733,321	1,733,321	1,733,321	1,185,882	1,185,882	1,185,882	627,131	627,131	627,131

Standard errors in parentheses
Omitted: SMEs - Age >= 10 years - Water and Electricity Distribution
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

- Despite a seemingly positive impact of higher yearly temperatures change on total outstanding loans, the growth rate of loans is negative.
- A dynamic adjustment phenomenon impacting exposed firms is at play.

Event–Study – de Chaisemartin & D'Haultfœuille (2023)

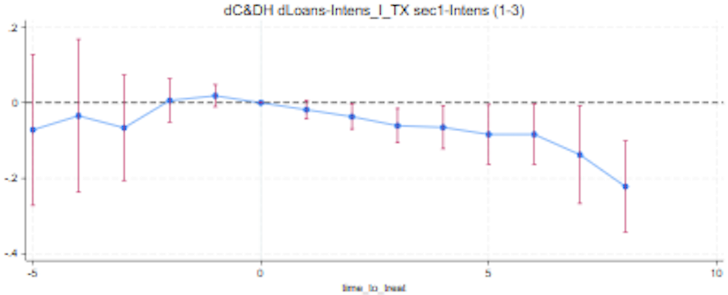
Figure 1: Effect of Excessive Heat Exposure (TX) on Loans Growth



- Non-anticipation and parallel-trends assumptions hold 6 periods before exposure.
- Exposed firms experience loans' growth rate −2.6%***. This effect builds up over time, reaching −16.1%*** after 8 years of exposure.
- The average total effect on loans' growth is −4.3%***.

Results: Event–Study – by sector

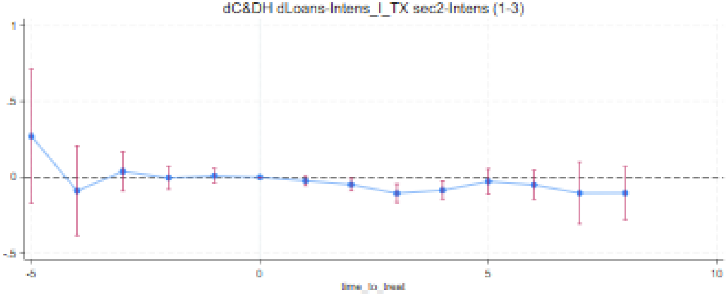
Figure 2: Effect of TX deviation for Trade & Transport Sector on Loans Growth



→ Consistent effect building up over the years, reaching -20% the last period.
→ For instance, if the non-exposed firms' loans growth is 5%, the exposed firms' loans growth is 4%, that is, 20% lower.

Results: Event–Study – by sector

Figure 3: Effect of TX deviation for Construction & Real Estate Sector on Loans Growth



→ Significant effect starting after 2 periods (around -7%), but no longer significant after the 5^{th} period.

Results: Event–Study – by sector

Some preliminary insights at this stage

- The by-sector estimation sheds light on heterogeneous sectoral effects.
- The impact on Construction & Real Estate sectors is less pronounced, and vanishes after 5/6 periods.
- The Accommodations & Leisure sector (Appendix) is more resilient, as it may exhibit higher sales performance (Addoum et al., 2021)

Event–Study: Other temperature indicators

Figure 4: Effects by industry & Temperature indicator on Loans Growth

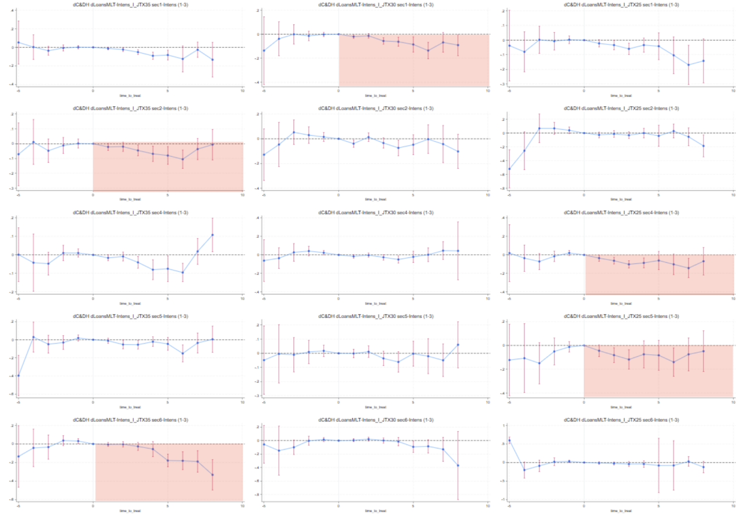
Event–Study – Other temperature indicators

Some additional insights

- Sectors are sensitive to different temperature indicators.
- While the Construction & Real Estate sector was not very responsive to the TX deviation indicator, we can see now that it is more sensitive to the variation of Days $> 35°C$ compared to historical levels.
- We also observe that the & Manufacturing & Mining sector is responsive for the indicator excess Days $> 25°C$ over the baseline period.
- While Trade & Transport and Services & ICT sectors exhibits the same impact of the TX indicator, they are more responsive to different temperature indicators.
- We can also see that the Accommodations & Leisure sector has some responsiveness to the Days $> 25°C$ indicator.

Event–Study – Other temperature indicators (MLT)

Figure 5: Effects on MLT Loans Growth



Event–Study – Other temperature indicators (MLT)

Loans maturity matters, too

- We observe heterogeneous effects for loans maturities.
- Medium & long-term loans are the main drivers of the lower loans' growth experienced by exposed firms.
- While banks are more cautious when lending to exposed firms, they tend to adopt a less stringent strategy when providing short-term financing.

Future Research Avenues

- Investigate firms and banks' adaptation efforts to temperature-shifts.
- Assess whether banks are adjusting their behavior by directly observing temperature shifts, or through more traditional channels, such as firms' performance indicators.
- Explore the impact on geographically diversified firms (multi-establishments)

Thank You!

Q&A