

Assessment and Management of Physical Risks in the Financial System

The case of Chile

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Second Annual Conference on Sustainable Finance

Financial Resilience: Physical Risks Quantification and Adaptation Viability

Panel 2 · Banco de México · October 21, 2026

Based on

Córdova et al. (2024), EEE N° 144, Banco Central de Chile

Córdova, Jiménez and García (2026), current research, UAI and BCCh

Outline

1

Why physical risk?

Why the Central Bank of Chile cares, and transmission channels

2

Past and present

Heat and labor productivity, 2010–2023

3

The future

Projected physical risks and exposure of sales and debt

4

Conclusions

Lessons and next steps

Why the Central Bank of Chile cares

1 · WHY IT MATTERS



Main climate threats

Coastal erosion, floods, heat and prolonged drought (IPCC, 2022).



Critical risk factors

Urban water security, hydro-dependent power, heat stress on labor and higher maximum temperatures.



A financial-stability issue

Climate risks become credit, market, underwriting, operational and liquidity risks, plus fiscal costs.

Concentrated in exposed macro-zones

88%

of population in North, Central and Metropolitan zones

95%

of firm sales in those three zones

87%

of bank loans in regions at extreme risk

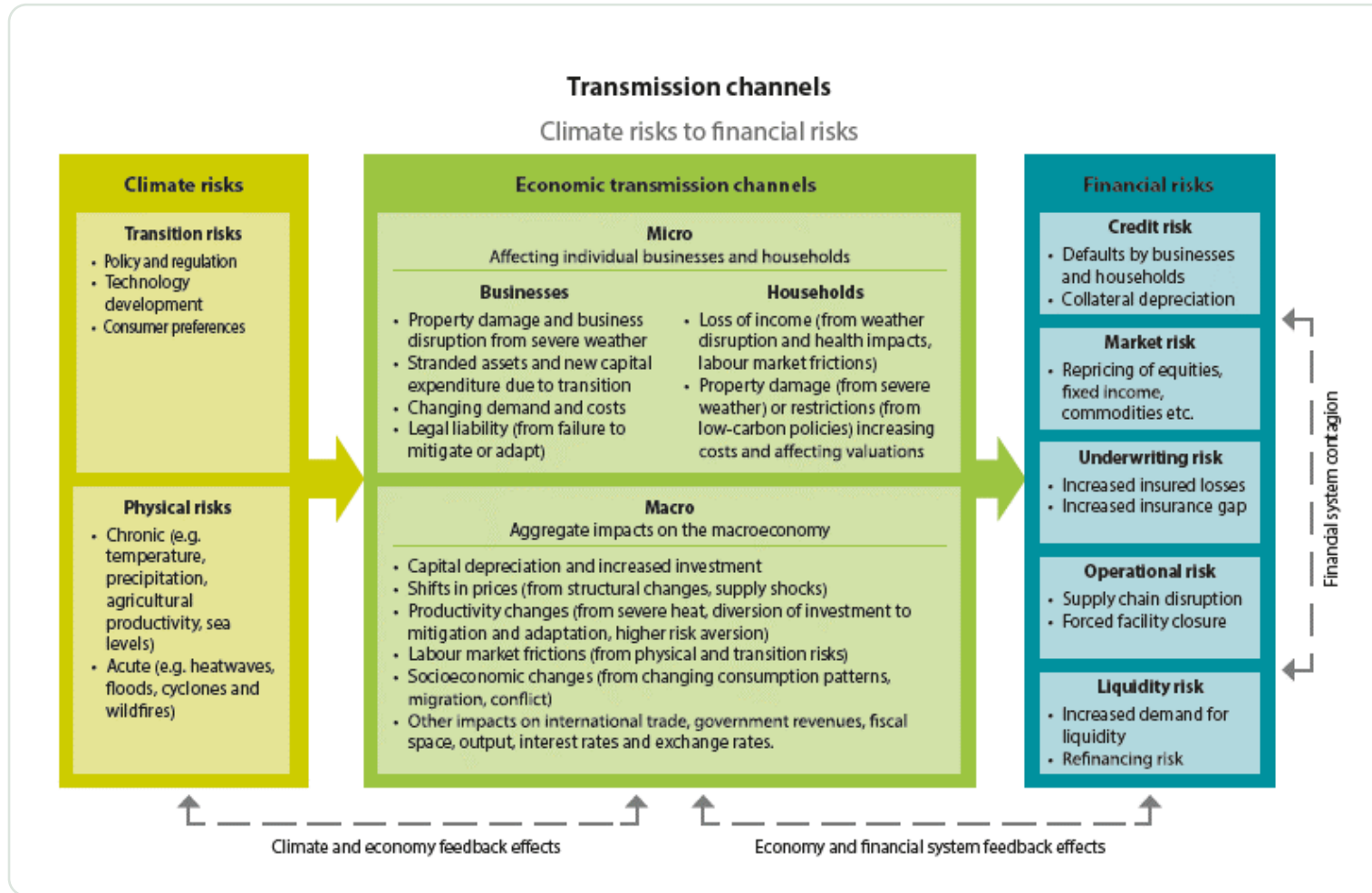
>30%

of property value exposed by 2050

Sources: Córdova et al. (2024), EEE 144; Córdova et al. (2022); Cortina & Madeira (2023).

How climate risks reach finance

1 · WHY IT MATTERS



1 Physical risks

Chronic: temperature, rain, sea level. Acute: heatwaves, floods, fires.

2 Micro channel

Firms lose revenue; households lose income and property value. Collateral falls.

3 Credit risk first

Losses raise PD and LGD. Uninsured losses fall on households, firms and the state.

Figure 1. Source: NGFS (2023), in Córdova et al. (2024), EEE 144.

Central banks abroad

~30%

of euro-area lending to firms with high physical risk

ECB (2021)

38%

of Portuguese loans to flood-exposed firms

Banco de Portugal (2023)

+50%

bank impairments under “no additional action”

Bank of England CBES (2022)

+1.11 pp

firm PD by 2070, Hot House vs. Orderly

Banco de España (2021)

Evidence for Chile



Hotter summers lower agriculture, forestry and fishing output

Hernández & Madeira (2021)



Heat reduces activity in most industries

Reszczyński (2024)



Mild GDP effects, but serious water stress and fire risk

Madeira (2022)

Common gap: geolocated data. EEE 144 uses tax and credit microdata for 345 municipalities.

Two questions

- How much does higher maximum temperature lower labor productivity?
- How do effects differ across sectors and municipalities?

Hypothesis

Heat lowers productivity, more so in resource-intensive sectors and exposed municipalities.

Variable	Source
Sales by municipality and sector	SII (tax records)
Workers by municipality and sector	INE (formal + informal)
Max. temperature (LST)	CIT-UAI, from MODIS

Source: Jiménez Hoffmann (2026), UAI.

2010–23

municipality × sector × year
panel

41,125

observations

17

sectors; Agriculture as base

44.5 °C

mean maximum LST, where
effects are evaluated

SEs clustered by sector × zone (55).

(4) Sectoral Cobb–Douglas technology

$$Y_{ijt} = A_{ijt} K_{ijt}^{\alpha_j} L_{ijt}^{1 - \alpha_j}$$

i = municipality, j = sector, t = year. Climate acts only through TFP (A).

(3) Temperature as a productivity shock

$$A_{ijt} = \exp(\beta_{1j}T_{it} + \beta_{2j}T_{it}^2 + a_i + a_j + a_t)$$

T and T² non-linear damage

β_{1j}, β_{2j} sector-specific slopes

a_i, a_j, a_t persistent non-climate factors

T = annual maximum temperature. Source: Jiménez Hoffmann (2026).

(7) Productivity after cost minimization

$$\ln\left(\frac{Y_{ijt}}{L_{ijt}}\right) = \beta_{1j}T_{it} + \beta_{2j}T_{it}^2 + a_i + a_j + a_t + \alpha_j \ln\left(\frac{\alpha_j}{1-\alpha_j}\right) + \alpha_j \ln\left(\frac{w_{ijt}}{r_{ijt}}\right)$$



(11) Estimable specification

$$\begin{aligned} \ln(\text{Prod}_{ijt}) = & \beta_0 + (\beta_{1,0} + \beta_{1,1}\gamma_j)T_{it} + (\beta_{2,0} + \beta_{2,1}\gamma_j)T_{it}^2 \\ & + \delta X_{ijt} + \mu_i + \gamma_j + \lambda_t + \theta_{jt} + \varepsilon_{ijt} \end{aligned}$$

μ_i municipality FE

θ_{jt} sector × year FE

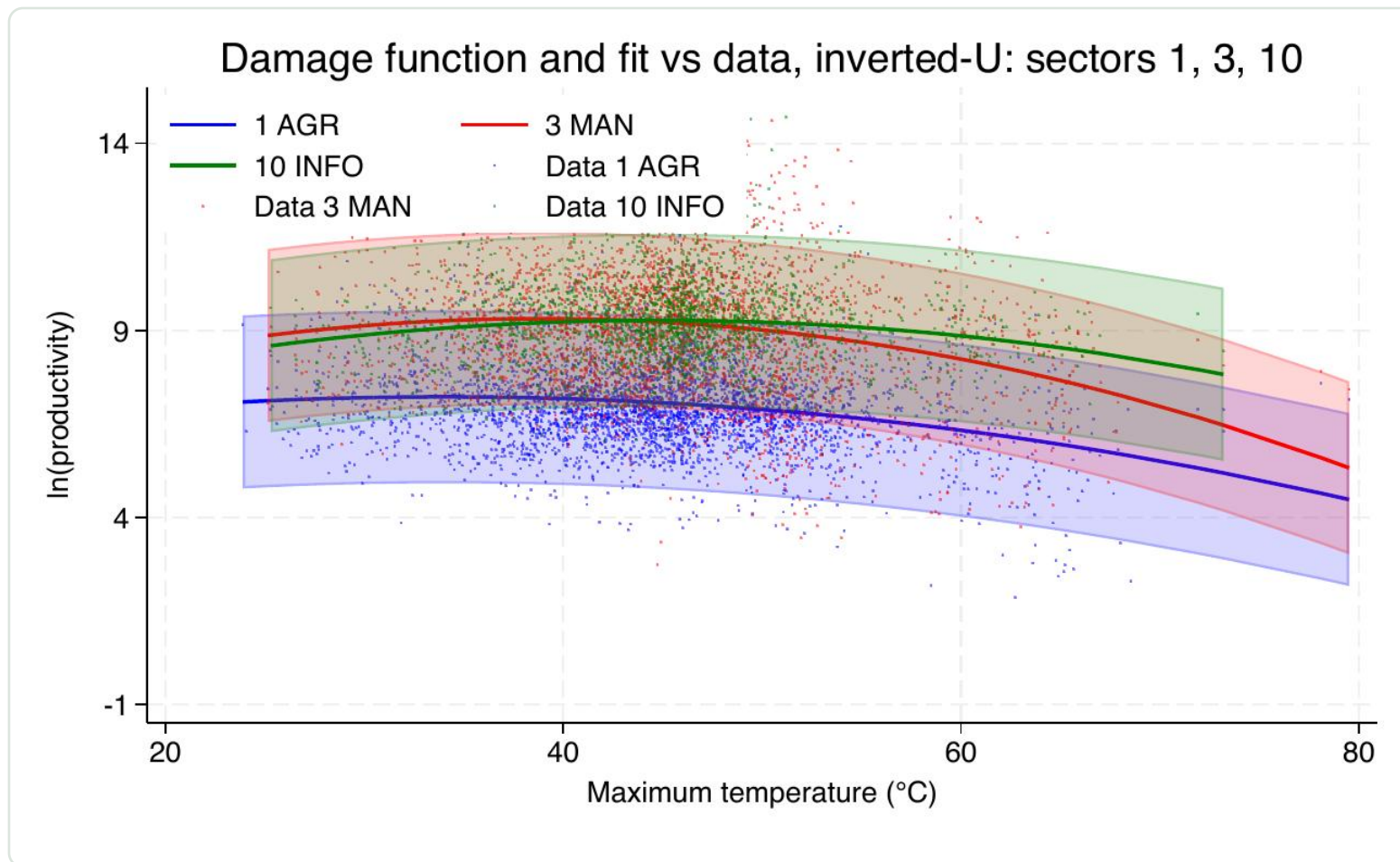
γ_j sectors, Agriculture base

vs. 2018 cross-section

Prod = Y/L; within-municipality identification. Source: Jiménez Hoffmann (2026).

Concave sectors: heat erodes productivity

2 · PAST AND PRESENT



-0.028

Agriculture: $\Delta \log$ productivity per $+1^{\circ}\text{C}$ at 44.5°C ($p < 0.001$)

Reading the figure

- Inverted U: Agriculture, Manufacturing, ICT
- Same in Finance, Real estate, Professional
- Panel: T 0.091, T^2 -0.0013 ($p < 0.05$)

Figure 7 (top left). Source: Jiménez Hoffmann (2026).

Convex sectors: adaptation, not gains from heat

2 · PAST AND PRESENT

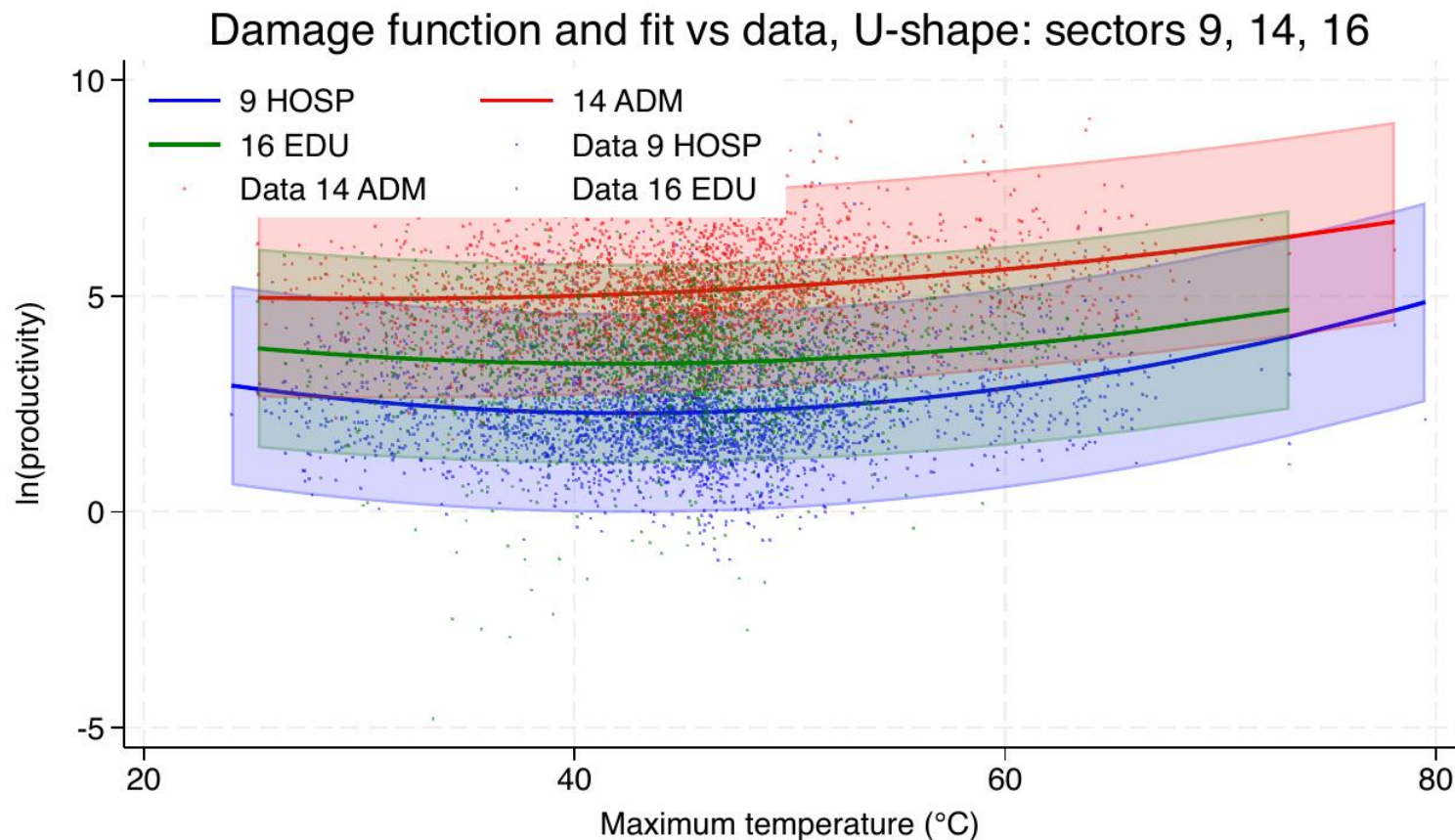


Figure 7 (mid-center left). Source: Jiménez Hoffmann (2026).

Identification matters

Δ ME Mining vs. Agr.	Estimate
Cross-section 2018	-0.069***
Panel 2010–2023	+0.059***

Cross-sections absorb municipal traits.

Shocks persist

$\rho_1 = 0.62$, $\rho_2 = 0.14$ (FE): heat shocks linger for years. Arellano–Bond is weaker.

Measuring forward-looking exposure

3 · THE FUTURE



Physical risk · ARClim

Climate-risk atlas: threat × exposure × sensitivity, by municipality. ~2050 vs. 1980–2010, RCP8.5.



Sales · SII e-invoices

All 2022 firm invoices, with seller and buyer location. USD 42.8bn in Dec-2022 alone.



Debt · CMF registry

Commercial bank debt of every firm, Dec-2022.

Exposure index

$$e_{it} = \ln(r_{it} \times f_{it})$$

r = risk, f = sales or debt, both in $[0, 1]$.

Five risks, 345 municipalities



Water safety



Extreme heat



Urban fires



Hydro generation



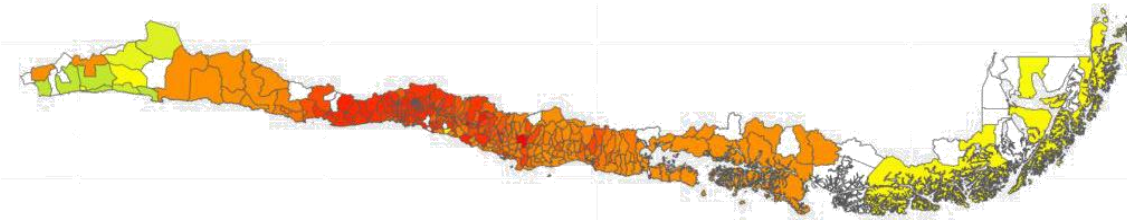
Heat mortality

Source: Córdova et al. (2024), EEE 144.

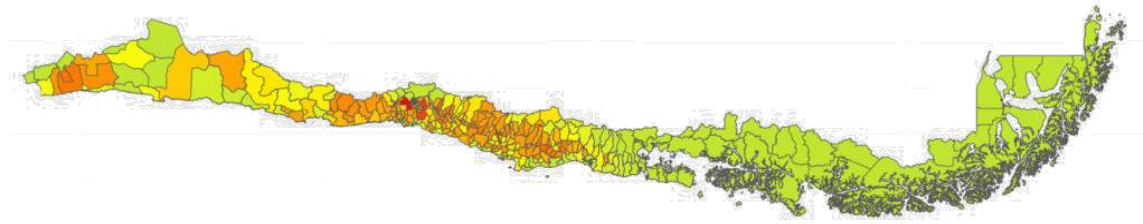
Where physical risks will rise

3 · THE FUTURE

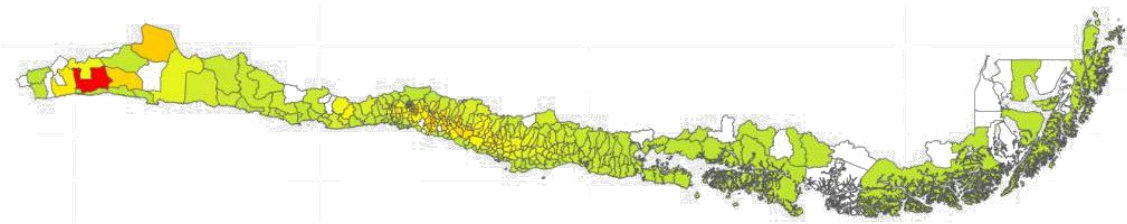
Water safety Highest in Valparaíso and Santiago



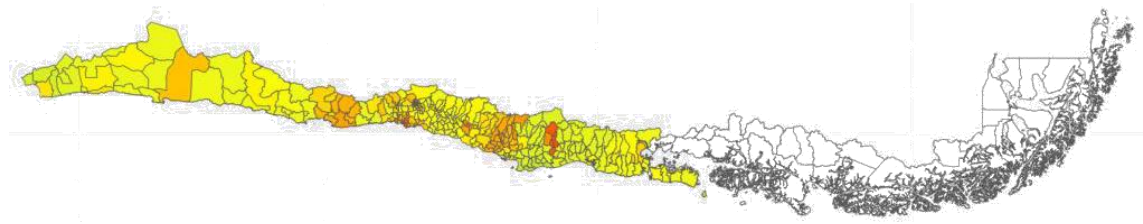
Extreme heat Largest rise in Santiago and south-center



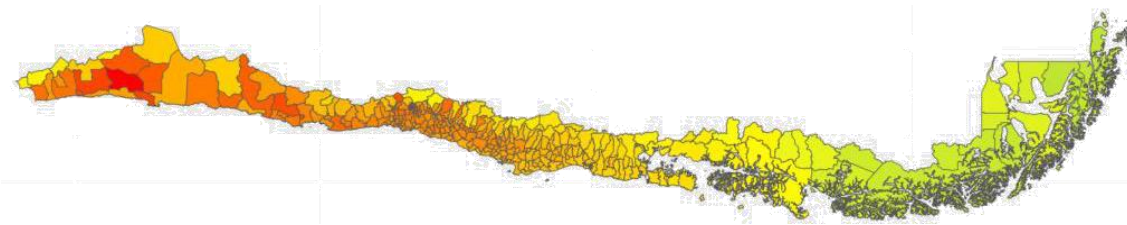
Urban fires Generally low



Hydroelectric generation Highest in the center



Heat mortality Center and north most exposed



Risk index (0 = low, 1 = high)



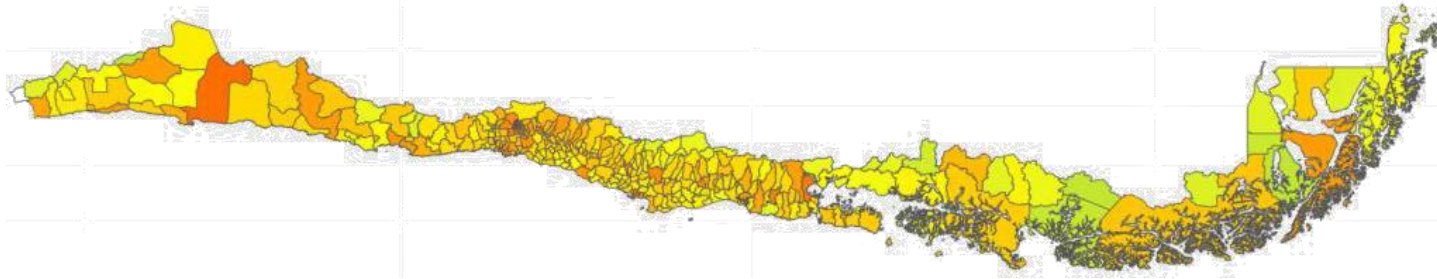
Rotated 90°: north on the left, coast at the bottom. Blank = no data.

Annex 1.1. Source: Central Bank of Chile, ARClm data.

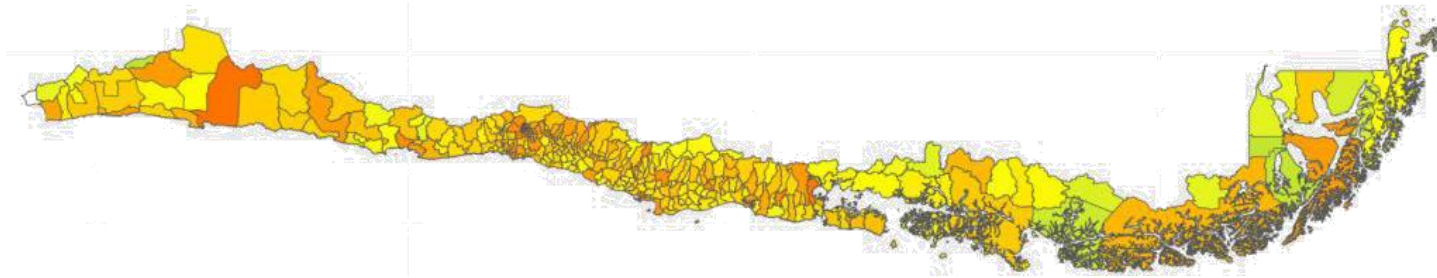
Where the money is: sales and bank debt

3 · THE FUTURE

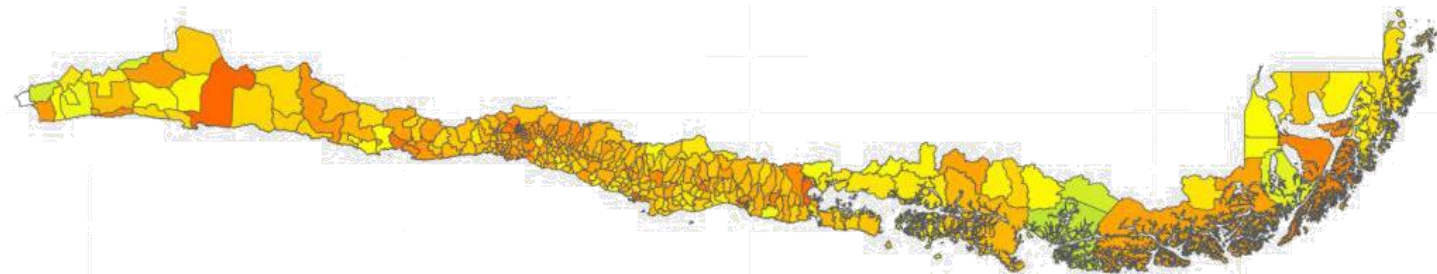
Administrative sales (e-invoices)



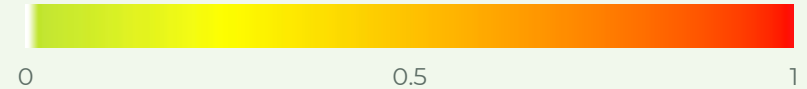
Total sales



Total bank debt



Level (0 = low, 1 = high)



Sales and debt move together



Santiago concentrates both

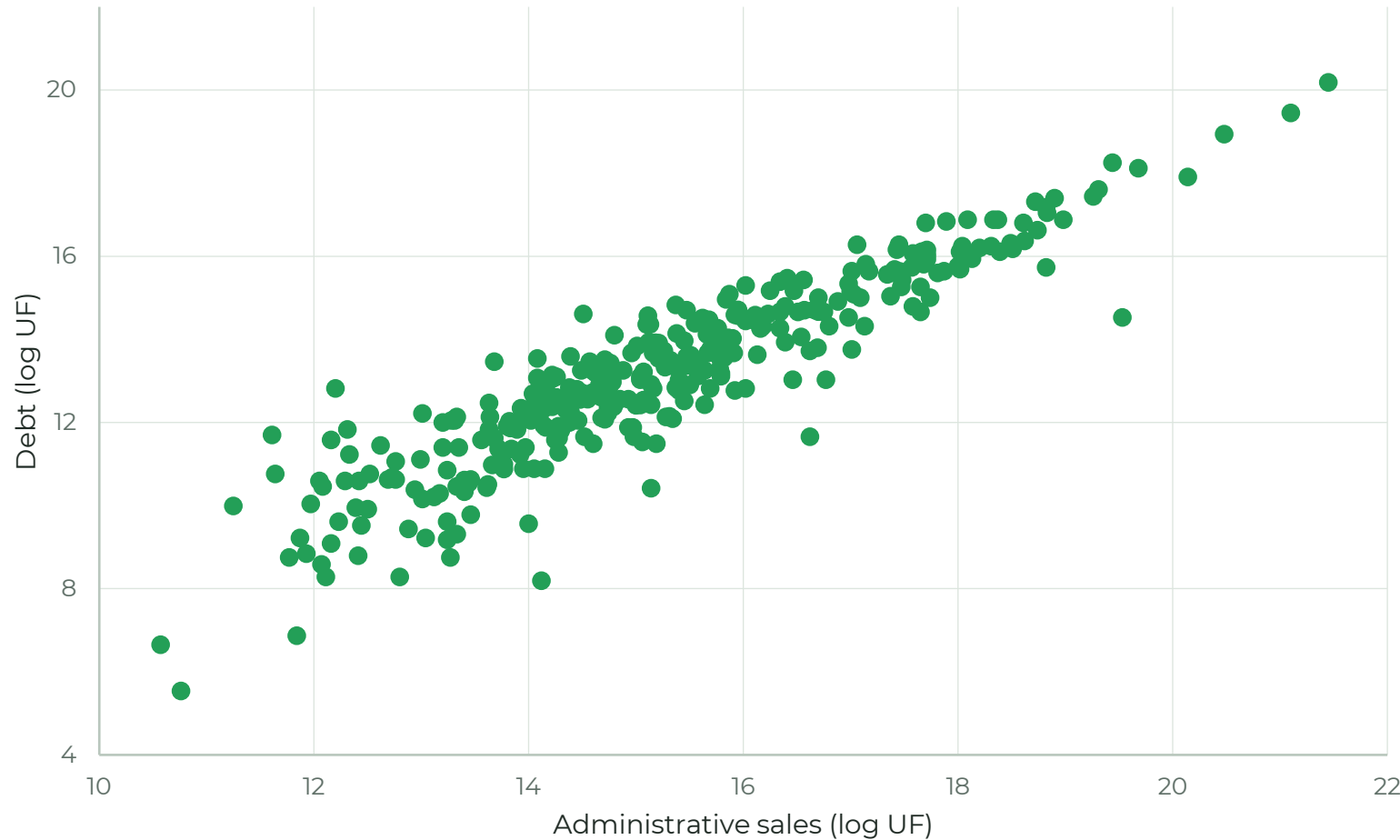


Antofagasta stands out (mining)

Annex 1.1.1. Source: Central Bank of Chile, SII data. North on the left.

Sales and bank debt move together

3 · THE FUTURE



$$\rho \approx 0.92$$

correlation, log sales vs. log debt

$$\approx 1.07$$

slope: debt rises one-for-one with sales

Banks lend where activity is: risk to activity is risk to banks.

Figure 2.1, redrawn. Source: Córdova et al. (2024), EEE 144.

Debt sits where water risk is high

3 · THE FUTURE

Figure 2.2 Water safety

Most debt and sales face high water risk

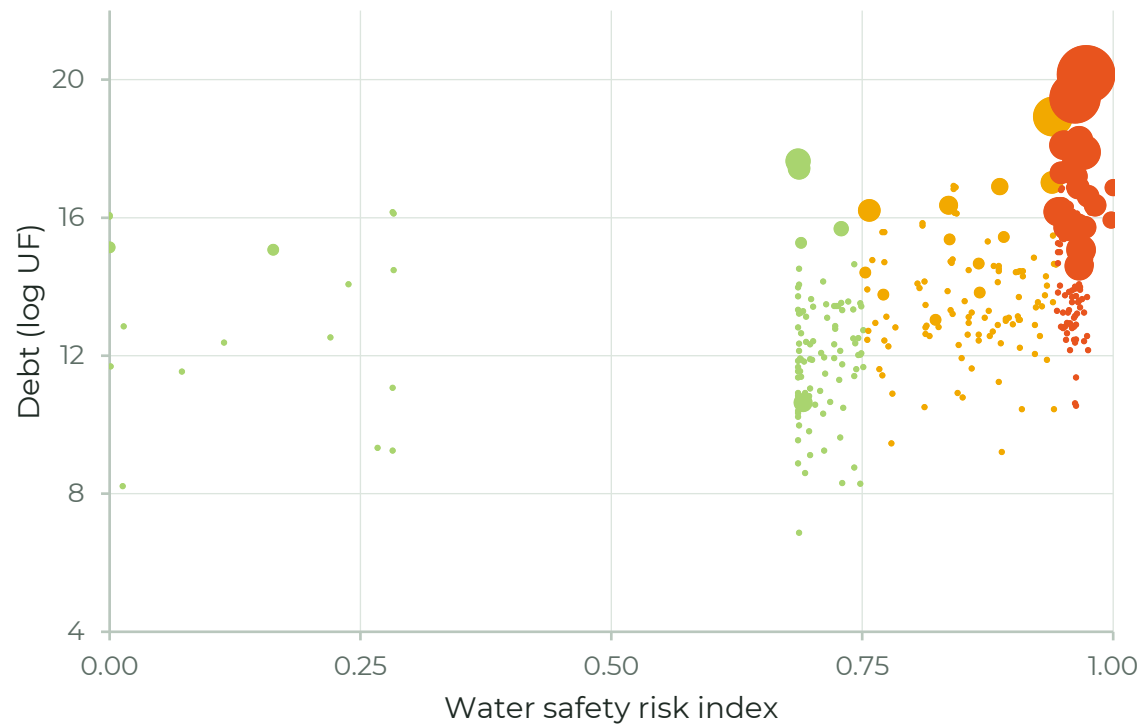
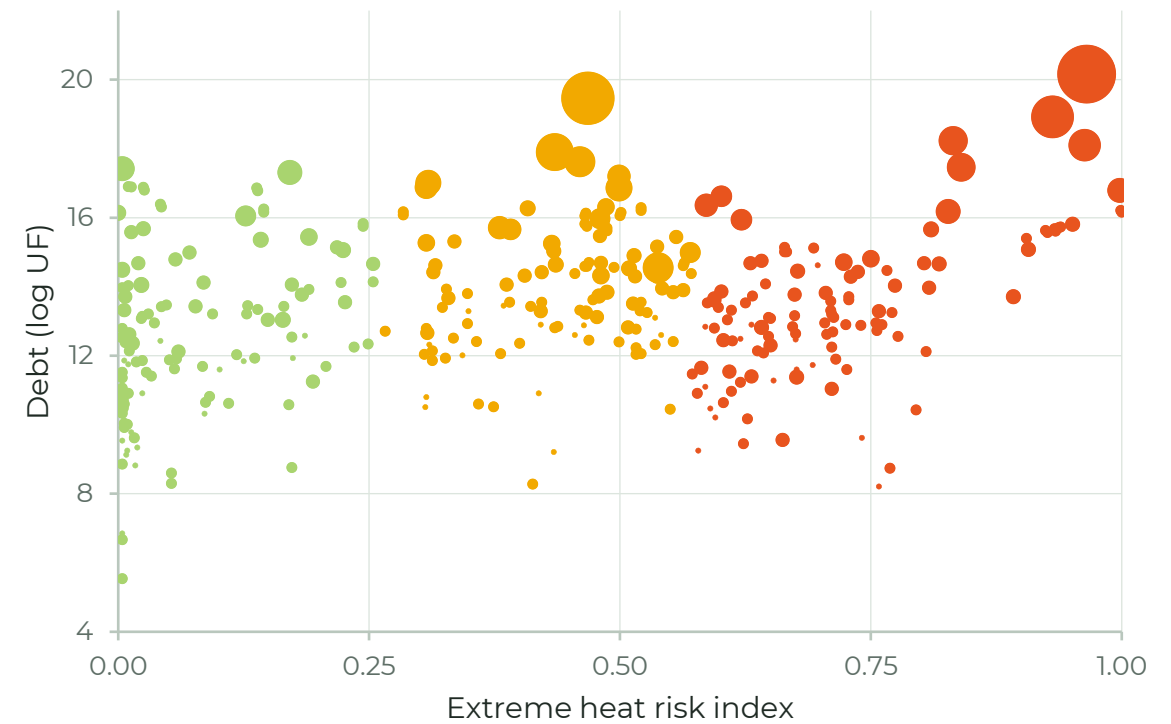


Figure 2.3 Extreme heat

Exposure spread more evenly



● Low risk ● Medium risk ● High risk

Risk terciles · bubble area = sales

Figures 2.2–2.3, redrawn. Source: Córdova et al. (2024), EEE 144.

Heat mortality tracks density; fires do not

3 · THE FUTURE

Figure 2.4 Heat mortality

Higher where debt and sales concentrate

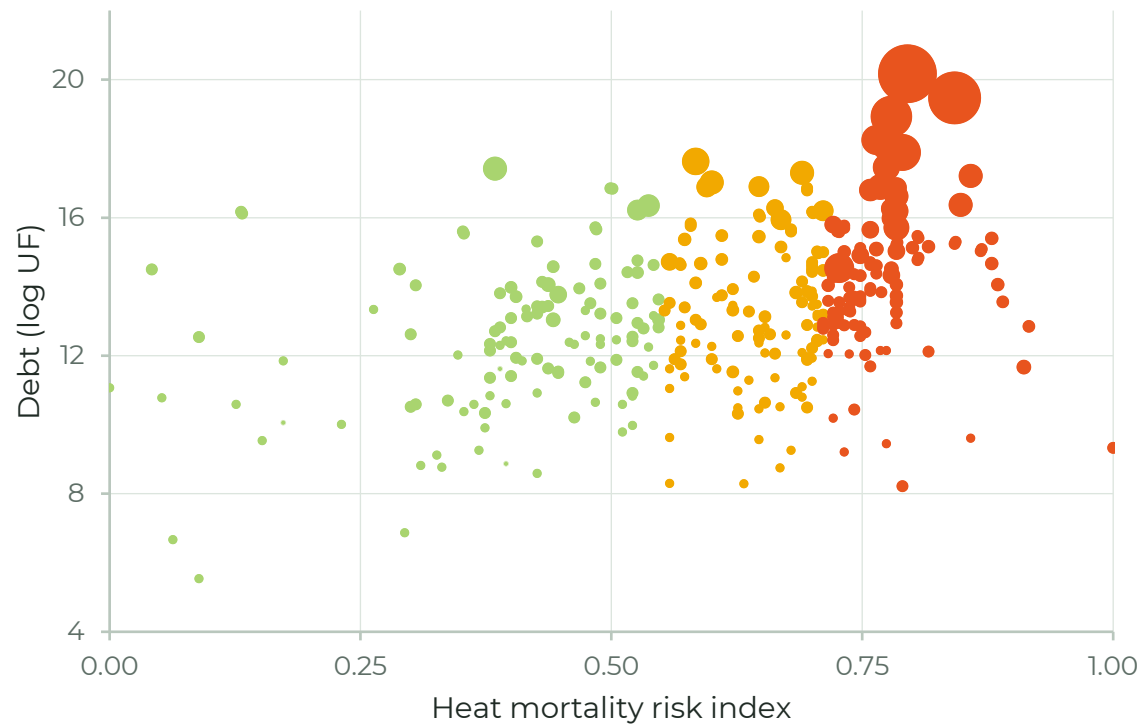
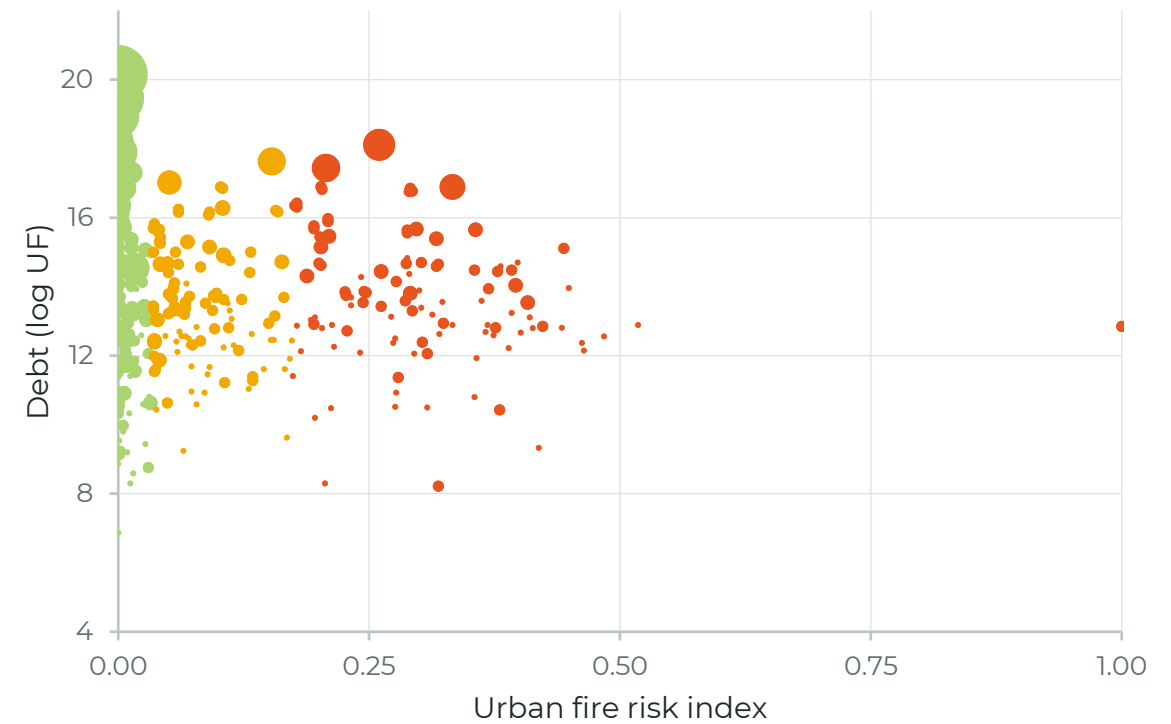


Figure 2.5 Urban fires

Big borrowers mostly in low-risk areas



● Low risk ● Medium risk ● High risk

Risk terciles · bubble area = sales

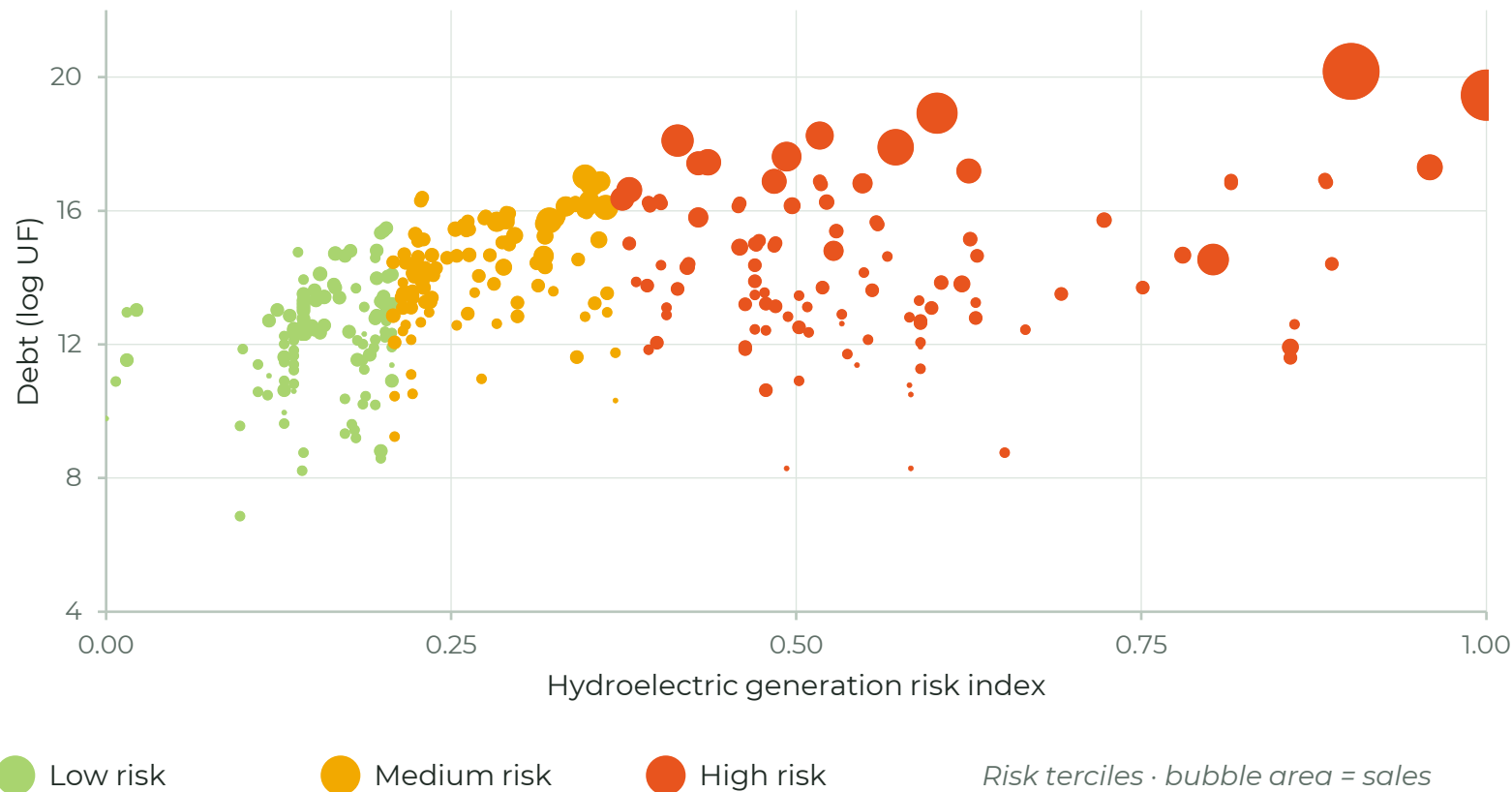
Figures 2.4–2.5, redrawn. Source: Córdova et al. (2024), EEE 144.

Hydro risk: low for most, high for the largest

3 · THE FUTURE

Figure 2.6 Hydroelectric generation cost risk

Most are low risk; the largest bubbles are high



Reading Figures 2.2–2.6

- Exposure varies by risk
- Water, heat mortality, hydro: big borrowers at high risk
- Heat is spread out; fires miss big borrowers
- Hydro: ~25% of electricity

Figure 2.6, redrawn. Source: Córdova et al. (2024), EEE 144.

High-risk municipalities hold most sales and debt

3 · THE FUTURE

Adm. sales (%)	Water safety	Extreme heat	Urban fires	Heat mortality	Hydro generation
Low risk	8.0	11.7	70.9	6.6	3.4
Medium risk	18.4	42.4	13.5	15.7	19.6
High risk	73.5	46.0	15.6	77.7	77.0

74–83%

in high-risk areas: water, heat mortality, hydro

Debt (%)	Water safety	Extreme heat	Urban fires	Heat mortality	Hydro generation
Low risk	7.2	11.6	73.8	6.6	2.2
Medium risk	18.2	34.5	11.5	15.6	15.3
High risk	74.6	53.9	14.8	77.8	82.5

~15%

for urban fires

By buyer location (Table 2b), shares are similar: little diversification.

Table 2a, by seller location (terciles). Source: Córdova et al. (2024), EEE 144.

Conclusions (I): financial exposure

4 · CONCLUSIONS



Closing data gaps

Tax, credit and ARClm data give firm-level exposures in all 345 municipalities.



Different risks, different exposures

Concentration varies by risk. Results hold for both sales measures.



High concentration

Sales and debt cluster in Santiago, highly exposed on both counts. Antofagasta stands out.



Next step

Have banks cut or repriced exposure to affected zones?
Work in progress.



Water and heat dominate

Central Chile faces most water and heat risk. Half of sales and debt face more heat; 15% face fires.

Source: Córdova et al. (2024), EEE 144, Banco Central de Chile.

1

Non-linear and heterogeneous

Some sectors are concave (inverted U), others convex (U).

2

Material losses in Agriculture

At 44.5 °C, +1 °C lowers productivity by ~2.7%.

3

Convexity ≠ benefit

U shapes reflect adaptation or location, not gains.

4

Panel over cross-section

Spatial estimates are biased; within variation is closer to causal.

5

Shocks persist

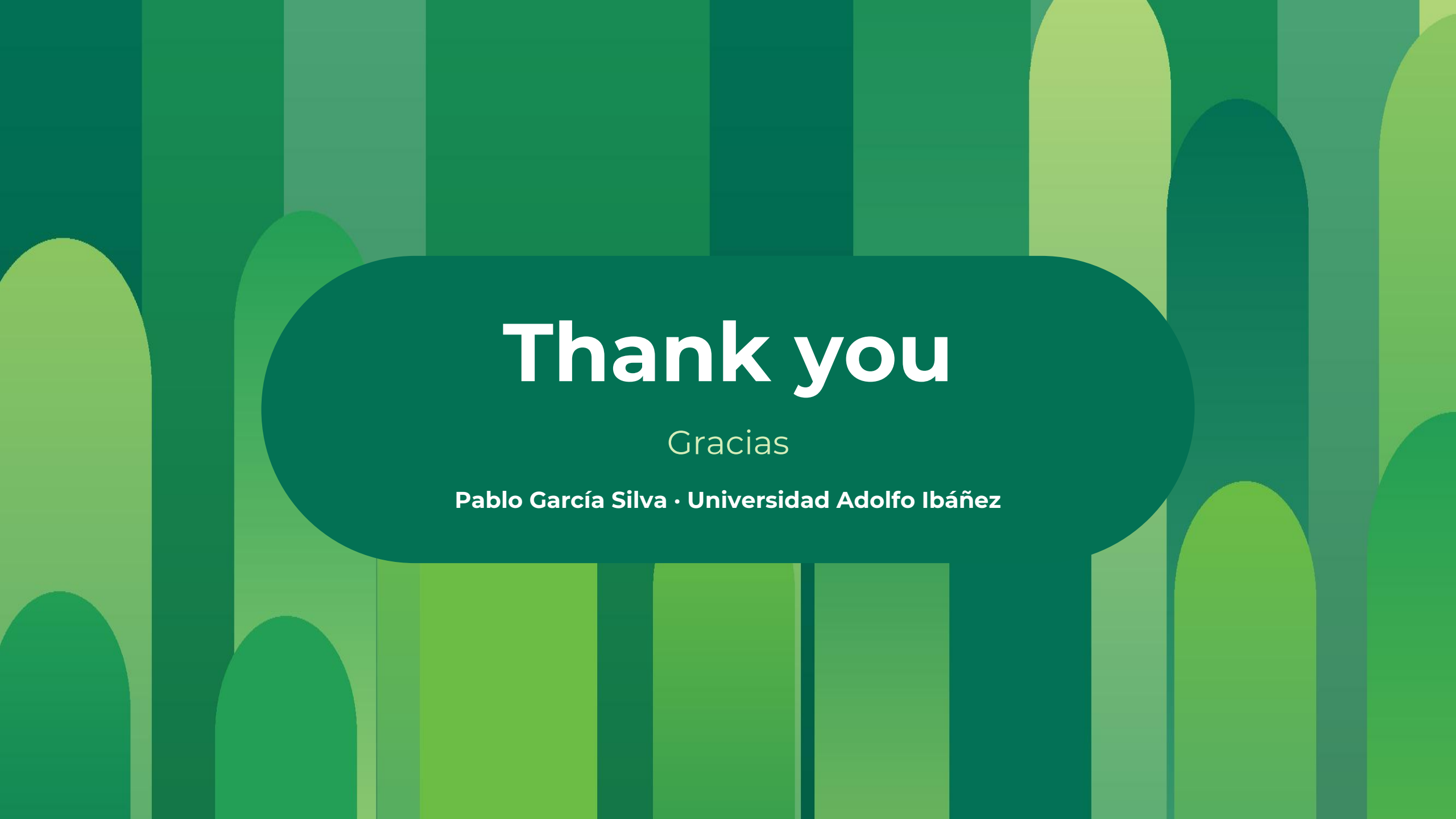
Strong inertia: heat shocks spread over time.

Bringing both together

- Physical risk already shows in productivity data
- Damage varies by sector and place: geolocate exposure
- Microdata make this feasible in emerging economies
- Next: damage functions in stress tests; banks' response

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Sources: Jiménez Hoffmann (2026); Córdova et al. (2024).



Thank you

Gracias

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