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Temperature shocks could accelerate China's expansion of agricultural operations amid ageing trends

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Electronic supplementary material (ESM)

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Table S1. Variable descriptions and explanations

Variables	Definition	Mean	SD
Agricultural land rental			
Whether land is leased	1 if the family leased land, 0 otherwise	0.146	0.344
Temperature shocks			
Daytime temperature shocks	daytime temperature deviation divided by standard deviation	0.966	0.681
Deviation	difference between actual temperature and historical mean	0.704	0.526
Temperature (whole day) shocks	temperatures (whole day) deviation divided by standard deviation	0.975	0.678
Other variables			
Rainfall shocks	precipitation deviation divided by standard deviation	–0.360	0.848
Aging	percentage of the population over 65 years of age in the household size	0.158	0.280
Characteristics of farm head			
Whether working in agriculture	1 if the family head works in agriculture, 0 otherwise	0.849	1.622
Age	age of the family head	50.202	13.011
Gender	1 if the family head is male, 0 otherwise	0.554	0.697
Health	very good: 1; good: 2; general: 3; bad: 4; very bad: 5	3.145	1.351
Education	illiteracy: 0 → Ph.D: 9; no education: 10	2.127	2.749
Characteristics of the farm family			
Income	*per capita* household income	1.643	4.939
Agricultural labour	ratio of people working in family farming	0.434	0.348

Source: Data from the China Family Panel Studies (CFPS) and data collated by the authors

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Table S2. Impact of temperature shocks on agricultural land rental (main results)

Variables	(1)	(2)	(3)	(4)
	Estimated coefficient	Average marginal effect	Estimated coefficient	Average marginal effect
Daytime temperature shocks	0.081** (0.033)	0.0141** (0.006)	0.166*** (0.044)	0.028*** (0.007)
Rainfall shocks	–	–	0.079*** (0.025)	–
Whether working in agriculture	–	–	−1.607*** (0.057)	–
Age	–	–	−0.003* (0.001)	–
Gender	–	–	−0.033 (0.025)	–
Health	–	–	0.005 (0.012)	–
Education	–	–	0.001 (0.006)	–
Income	–	–	0.000 (0.000)	–
Agricultural labour	–	–	−1.607*** (0.057)	–
Provinces	yes	yes	yes	yes
Year	yes	yes	yes	yes
Constant	−1.796*** (0.176)	–	−0.983*** (0.188)	–
Observations	16 973	16 973	16 973	16 973
Number of households	3 494	3 494	3 494	3 494

***, ** and *significance at the 0.01, 0.05 and 0.1 levels, respectively; standard errors in parentheses; other controls are rainfall shocks, whether working in agriculture, age, gender, health, education, income, or agricultural labour

Source: Data from the China Family Panel Studies (CFPS) and data collated by the authors

Table S3. Robustness test of temperature shocks

Variables	(1)	(2)	(3)	(4)
	Estimated coefficient	Average marginal effect	Estimated coefficient	Average marginal effect
Deviation	0.171** (0.063)	0.029** (0.011)	–	–
Temperature (whole day) shocks	–	–	0.186*** (0.046)	0.031*** (0.008)
Other controls	yes	yes	yes	yes
Provinces	yes	yes	yes	yes
Year	yes	yes	yes	yes
Observations	16 973	16 973	16 973	16 973
Number of households	3 494	3 494	3 494	3 494

*** and **significance at the 0.01 and 0.05 levels, respectively; standard errors in parentheses

Source: Data from the China Family Panel Studies (CFPS) and data collated by the authors

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Table S4. Impacts of daytime temperature shocks on household family size

Variables	(1)
	Family size
Daytime temperature shocks	–0.035 (0.028)
Other controls	yes
Provinces	yes
Year	yes
Observations	16 973
Number of households	3 494

Source: Data from the China Family Panel Studies (CFPS) and data collated by the authors

Table S5. Mean differences in variables between small-scale and large-scale

Variables	(1)	(2)	(3)
	Small	Large	Diff
Agricultural labour	0.538 (0.269)	0.641 (0.864)	–0.104***
Value of agricultural products per ha	4.049 (18.086)	1.393 (4.994)	2.657***
Cost of seeds, fertilisers, and pesticides per ha	1.373 (6.778)	0.119 (0.382)	1.254***
Labour costs per ha	0.199 (2.307)	0.050 (0.216)	0.149
Cost of machine rental and irrigation per ha	0.214 (0.786)	0.013 (0.099)	0.201***
Other costs per ha	0.116 (1.211)	0.019 (0.161)	0.097

***significance at the 0.01 level; standard errors in parentheses

Source: Data from the China Family Panel Studies (CFPS) and data collated by the authors

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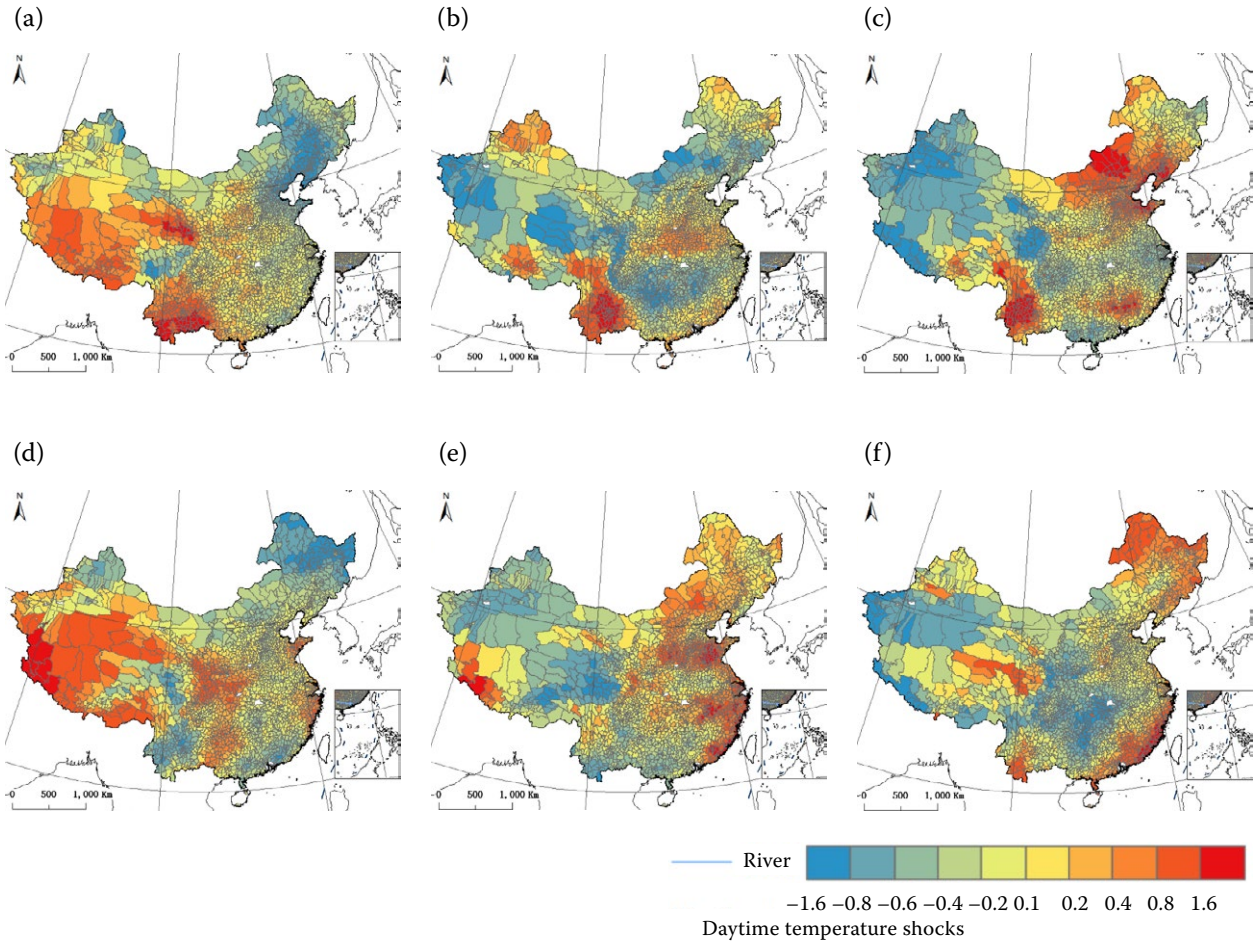
Figure S1. Regional distribution of temperature shocks



A–F represent the extent of temperature shocks in China in 2010, 2012, 2014, 2016, 2018, and 2020, respectively; due to limitations in data availability, Hainan Island and Taiwan Province are excluded from the analysis in this figure.

Source: Authors' own elaboration based on ERA5-Land temperature data

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Text S1. Reasons for choosing the probit model

The choice of a panel probit model over alternative approaches [linear probability model (LPM) and logit model] is justified as follows:

Rejection of LPM: The LPM is unsuitable for analysing binary decision-making in this study due to critical limitations. It assumes a linear relationship between independent variables and the probability of the binary dependent variable, risking predicted probabilities outside the [0,1] range (e.g. under extreme temperature shocks). Additionally, LPM suffers from heteroscedastic error terms, violating OLS assumptions and undermining parameter reliability, while failing to capture potential non-linear effects of temperature shocks (e.g. varying marginal effects with shock intensity).

Preference for probit over logit:

i) Distributional fit: Farmers' land rental decisions are a 'continuous and gradual' process, shaped by temperature shocks through mechanisms like declining net income and deteriorating working environments, involving gradual cost-benefit trade-offs rather than abrupt choices. The probit model, assuming a normally distributed latent variable with symmetric 'dense-in-the-middle' characteristics, better captures this gradual decision-making – most choices shift smoothly with shock intensity, with fewer extreme decisions. In contrast, the logit model's thicker-tailed logistic distribution is more suited to extreme or strongly preference-driven choices, aligning less with farmers' 'rational, incremental adjustment' behaviour.

ii) Disciplinary conventions: Probit is mainstream in agricultural and environmental economics for binary decisions (e.g. land transfer, technology adoption) related to climate shocks and resource allocation. Studies such as Qian et al. (2022) and Ren et al. (2023) use probit for analogous analyses, as do works on technology adoption and energy choice, enhancing cross-study comparability.

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