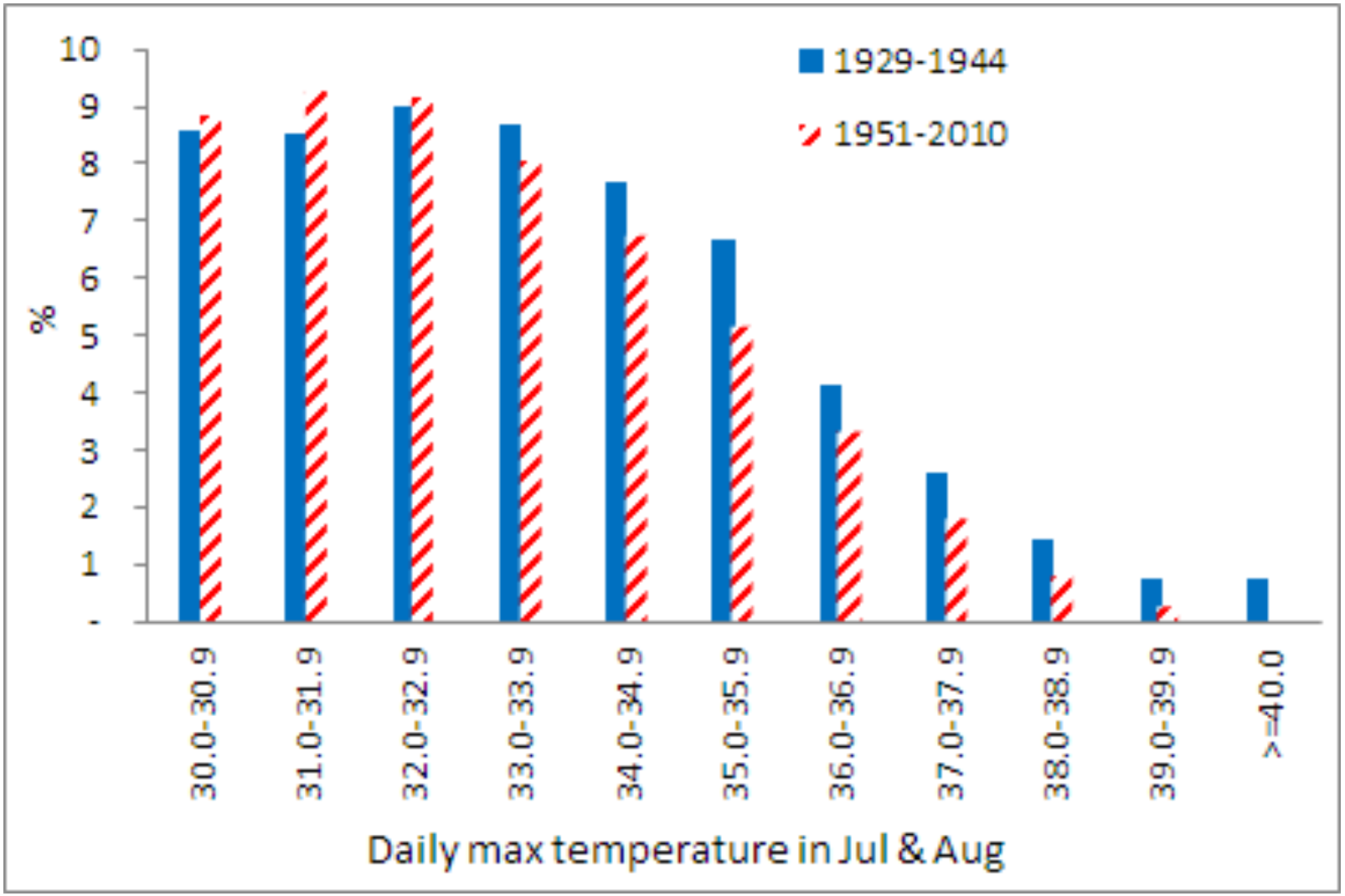
Climate change in China: Communism is cooler

I.P.L. Png
Junhong Chu
Yehning Chen

China, July and August daily max temperature: 1951-2010 vis-a-vis 1929-44



Findings

- Frequency of extreme temperatures (35ºC)
  - decreased sharply from 1954
  - increased from 2000 onward
- Effect limited to summer months (June-August)
- Effect more pronounced
  - At stations where average summer temperature in 1929-44 relatively higher
  - In provincial capitals
- Robust to
  - Control for aerosol effect (sunshine hours)
  - Sample, specification, method

Findings, cont'd

- Increased frequency of extreme temperatures from 2000 onward
  - More pronounced in stations with higher score for environmental transparency
  -

Outline

- Data
- Method
- Results
- Explanations
- Hot weather policy
- Discussion

Data sources: Historical China, 1912-49

- 國立中央研究院氣象研究所, 氣象月刊, Monthly Meteorological Bulletin, Academia Sinica, National Research Institute of Meteorology, Pei-Chi-Ko, Nanking, China, 1928-37
- 日本軍北支那氣象部, 北支那氣象月報, North China Monthly Meteorological Bulletin, North China Meteorological Department, Japanese Army, 1939-44
- Other observatories and agencies
  - Provinces: Fujian, Hunan, Jiangsu, Manchuria, Sichuan
  - Cities: Dalian, Qingdao, Society of Jesus Kiangnan Mission, Shanghai

Data sources: Modern China, 1951-2010

- China Meteorological Administration (CMA): Surface weather database, version 3.0 -- up to 824 stations
  - Minimum and maximum temperature
  - Sunshine
- Global Historical Climatology Network (GHCN) -- up to 199 stations
  - Minimum and maximum temperature

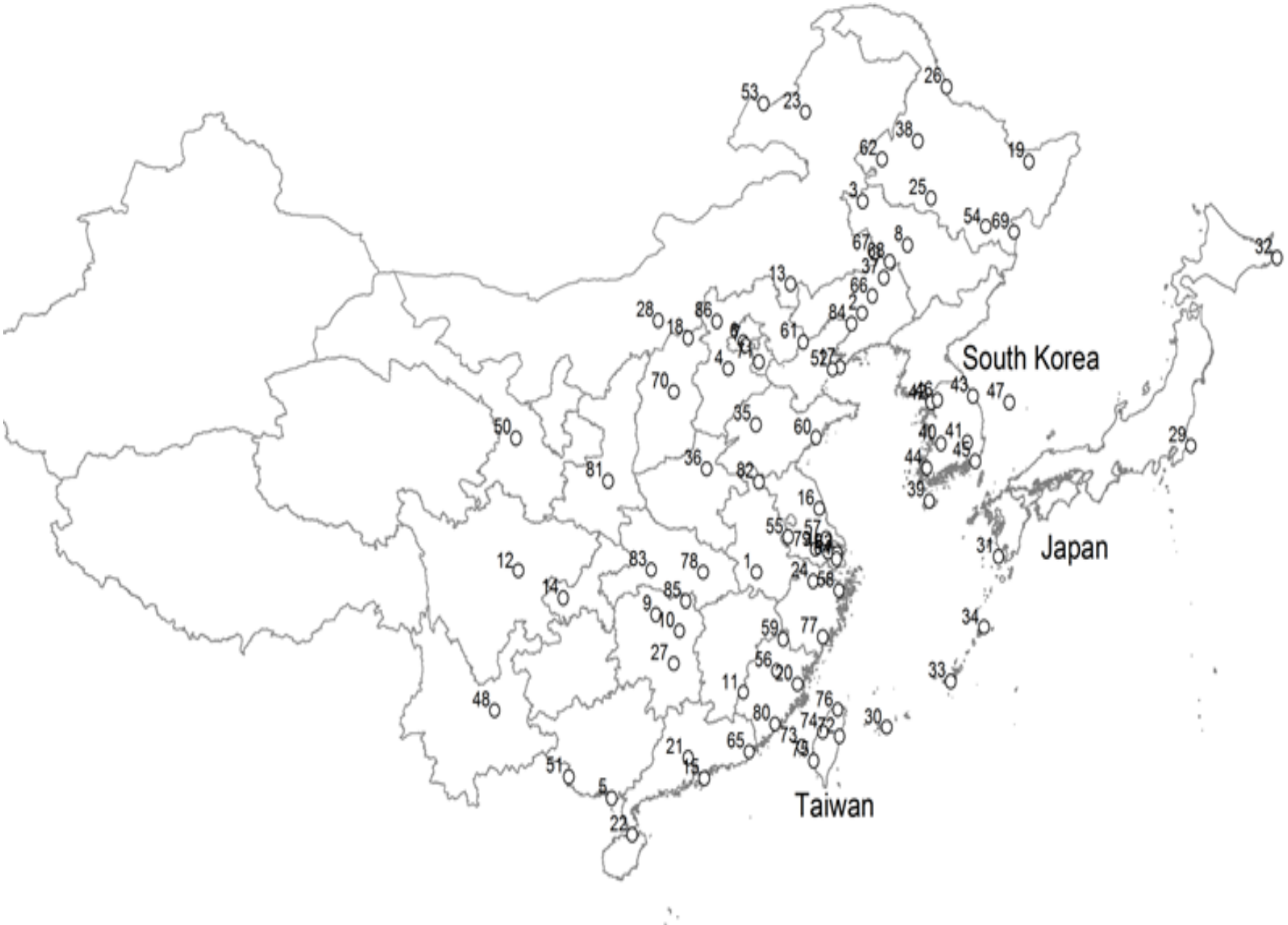
Data: Matching China stations

- Matching criteria
  - Location
    - Longitude and latitude: Distance < 10 kilometres
    - Difference in elevation < 100 metres
  - At least 5 years of records in 1929-1944 (with at least 6 months per year)
  - At least 19 stations in each year
- Matched data-set
  - 65 stations, 1929-44 and 1951-2010
  - 1,539,393 observations of daily max and min temperature
  - 1,318,497 observations of daily sunshine duration

Data sources: Non-mainland/foreign, 1929-2010

- Hong Kong Observatory
  - One station
- Japan Meteorological Agency
  - 6 stations in southwest
- Korea Meteorological Administration
  - 9 stations in west
- Taiwan: Central Weather Bureau
  - 5 stations in west
- Matched data-set
    - 21 stations, 1929-2010
    - 590,083 observations of daily max and min temperature
    - 450,942 observations of daily sunshine duration

Data: Stations



Data

- Quality
  - Conventional checks
  - Compared across sources
    - 1954 compilation of monthly averages (中国气温资料 / 中国气象局中国科学院地球物理研究所联合资料室编)
    - Multiple original sources
- Inhomogeneities
  - Movement of stations
  - Changes in technology, standards, and procedures

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Empirical strategy

- Difference in difference
  - 1929-1944: summer temperatures *more extreme* in China than foreign
  - 1954-2000: summer temperatures *less extreme* in China than foreign
- Benchmark for extreme: Probability of daily maximum temperature $\geq$35ºC

Method: Multiple regression

- Unit of analysis: Station + date
  - More robust to errors in data than annual or monthly model
  - More precise estimate -- annual/monthly average of daily extremes understates the effects
- Dependent variable:
  - Daily maximum temperature for each station
  - Probability of daily maximum temperature $\geq$ benchmark (35ºC) -- to investigate the frequency of extreme temperatures

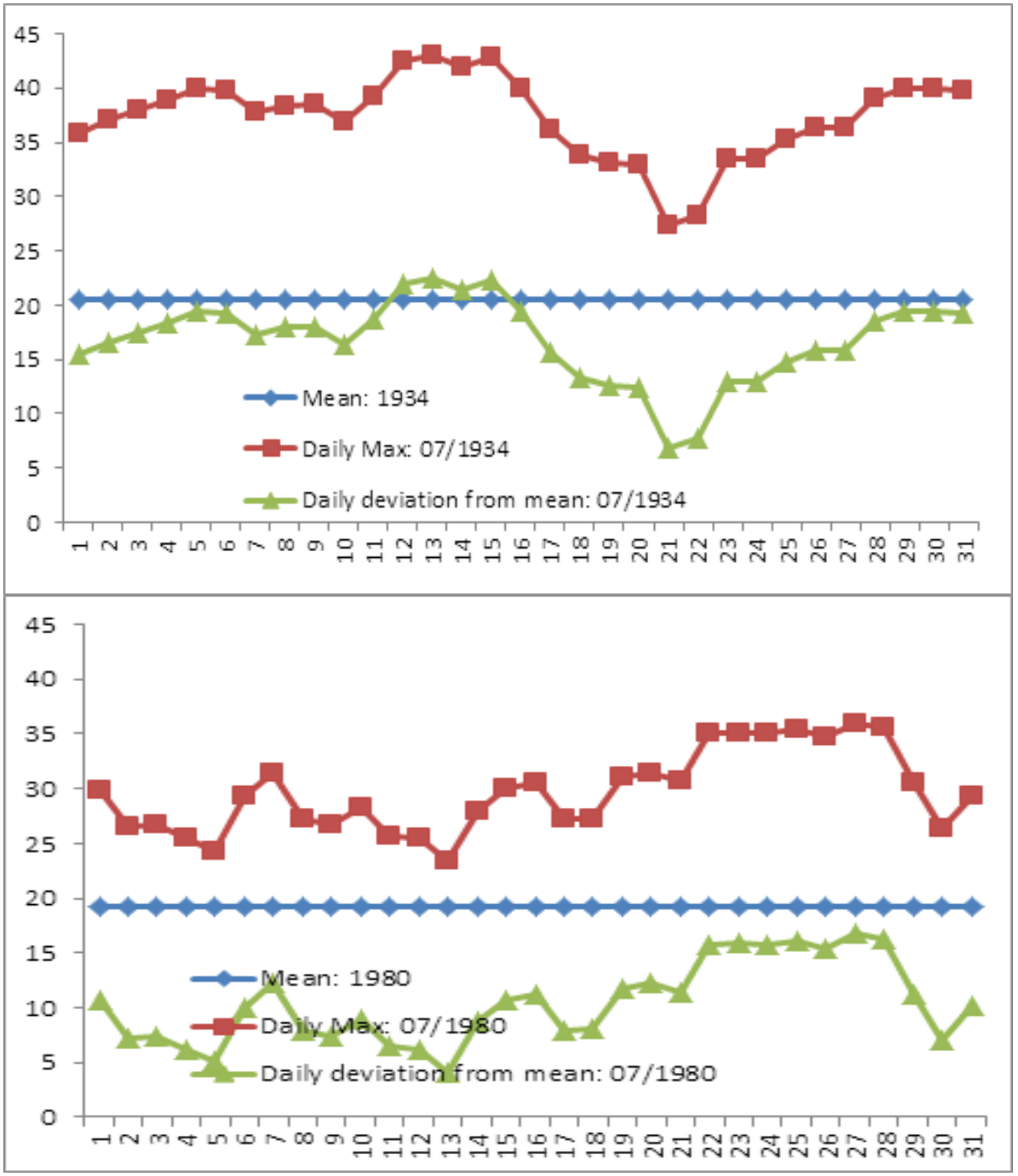
National model

- Dependent variable
  - Daily maximum temperature
  - Probability of daily maximum temperature ≥ benchmark (35ºC)
- Explanatory variables -- fixed effects
  - Stations (regional differences)
  - Years (average of dependent variable for year)
  - Months (seasonal differences)
  - China x years (average increment in dependent variable for China relative to foreign countries in each year)

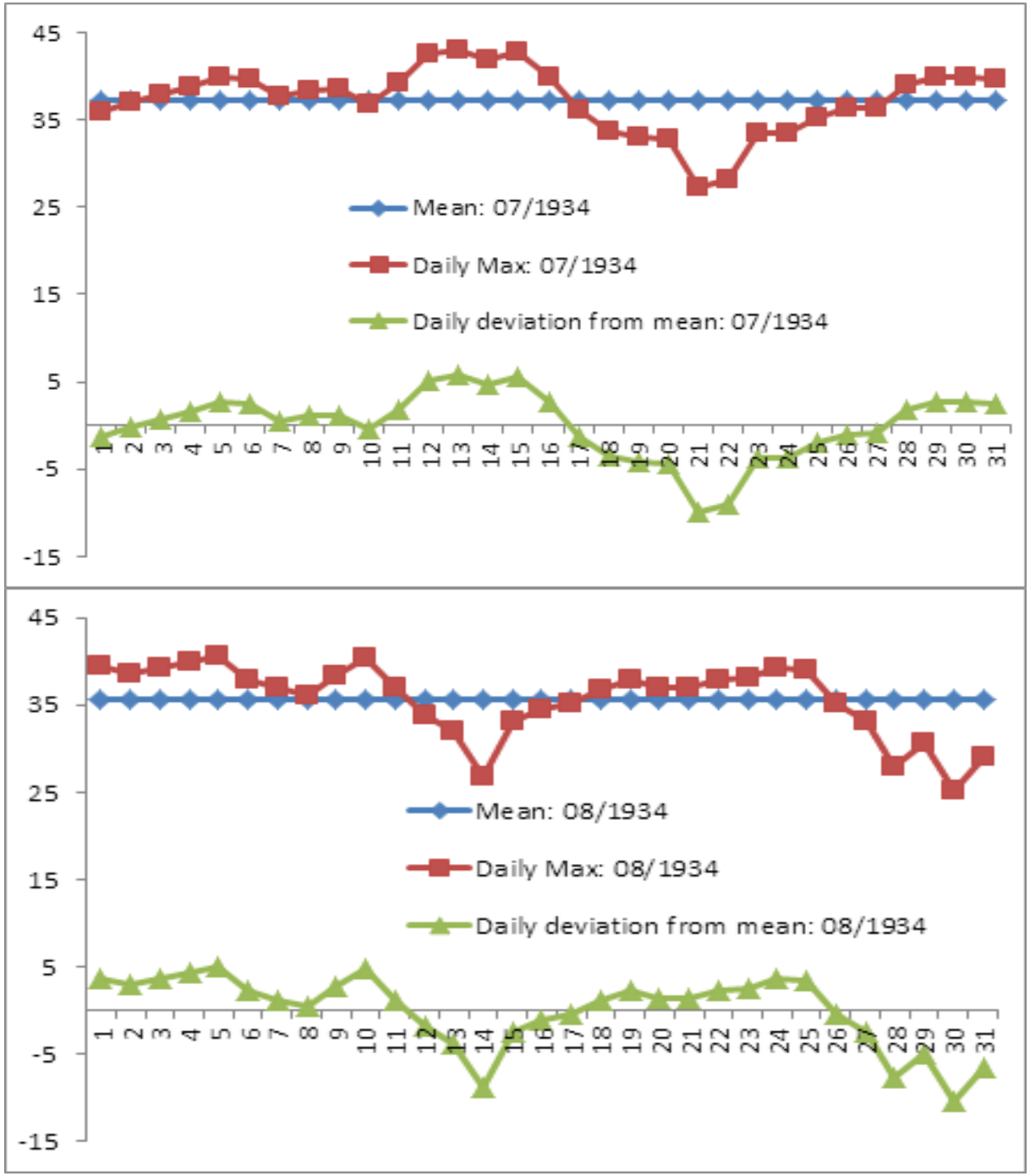
Station-specific model

- Dependent variable
  - Daily maximum temperature
  - Probability of daily maximum temperature ≥ benchmark (35ºC)
- Explanatory variables:
  - Fixed effects
    - Station-year: Urban heat island effect, movement of station, change in meteorological standard, change in recording procedure or personnel
    - Station-month: Differences in seasonality
  - Station x Post-1954 (including foreign stations)
  - [Standard errors clustered by station]

Daily max, Nanjing, July 1934 and 1980



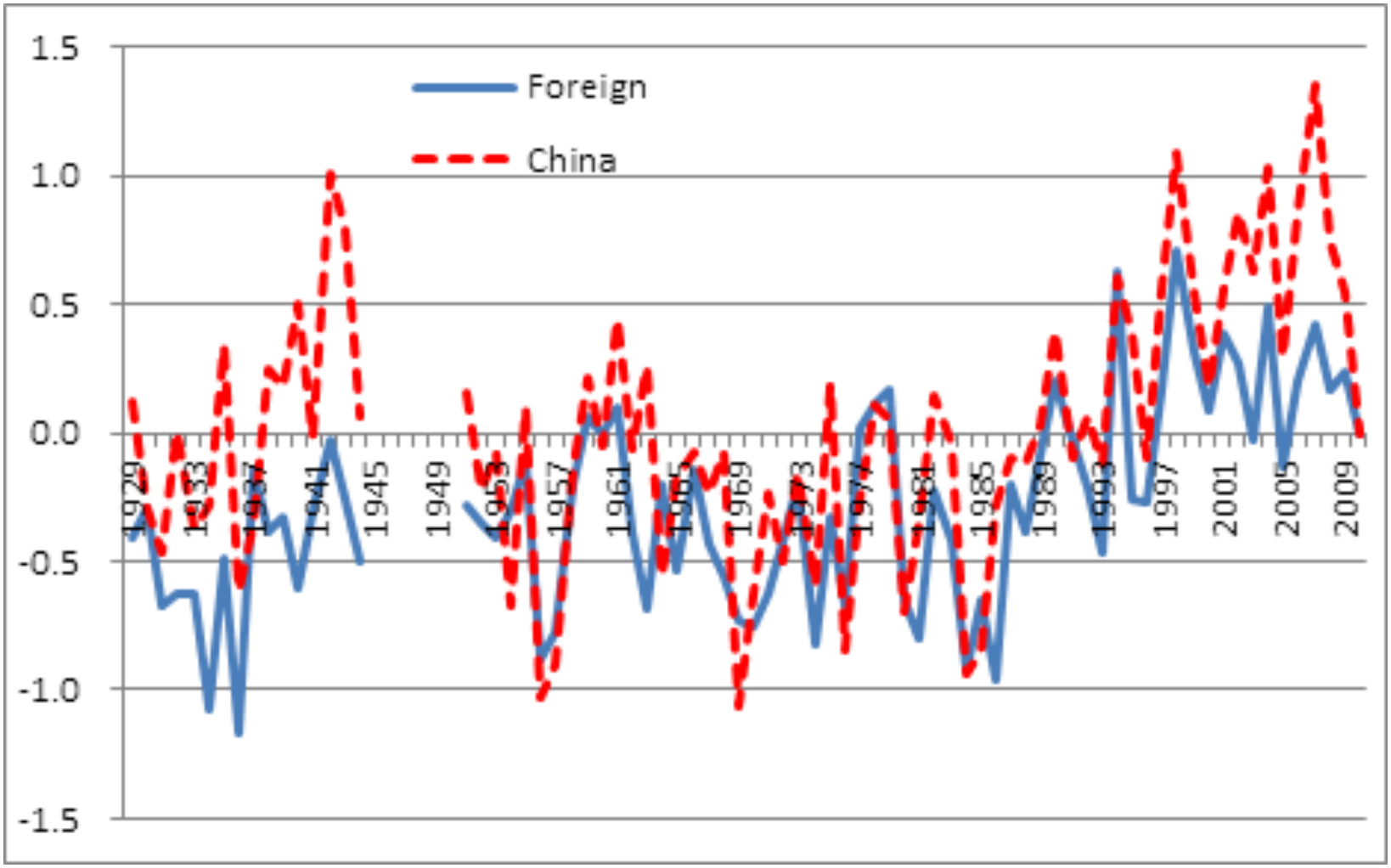
Daily max, Nanjing, July and Aug 1934



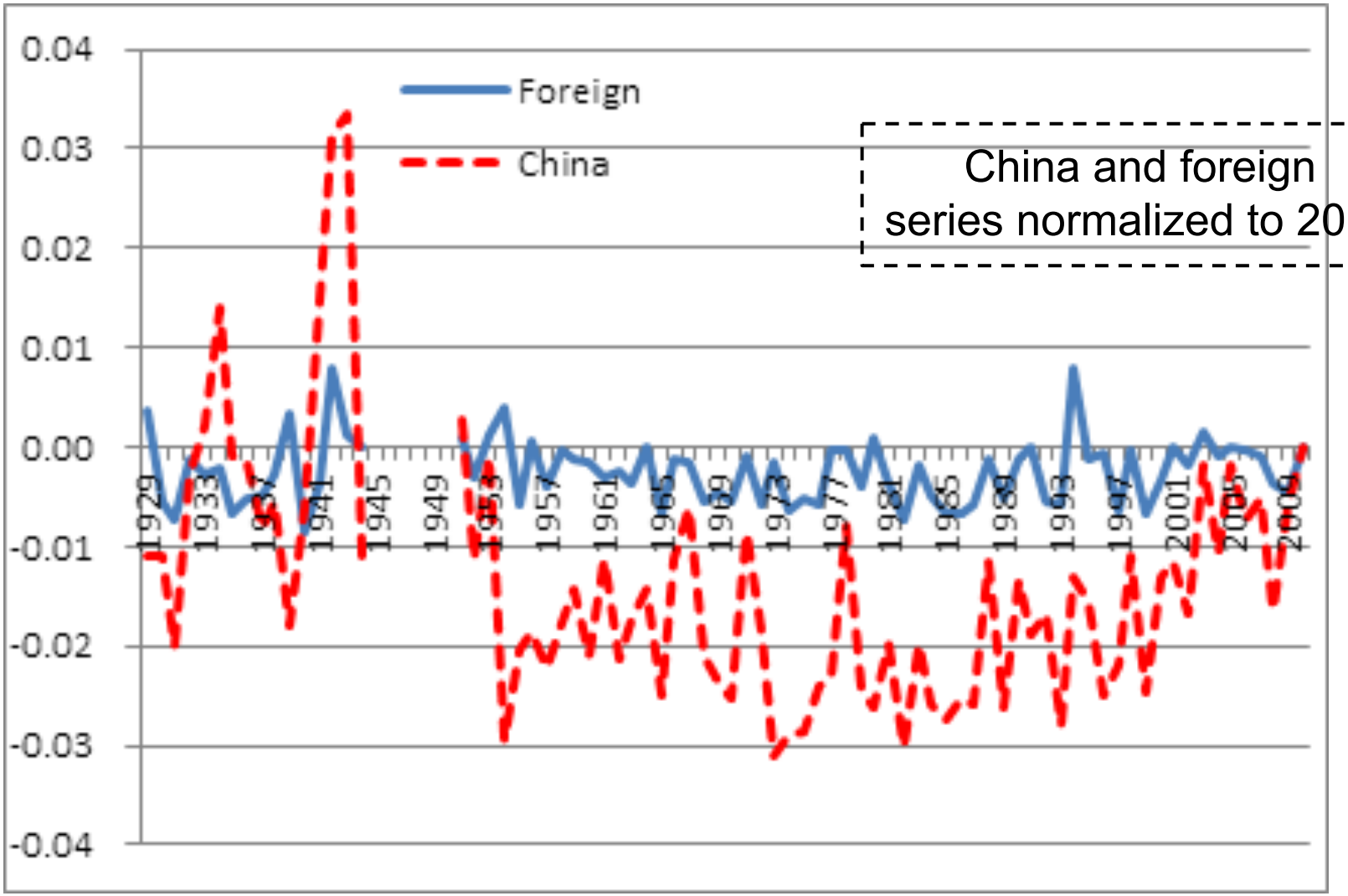
Outline

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  - National model
  - Station-specific model
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National model: Daily max temperature: Year fixed effects (annual average)

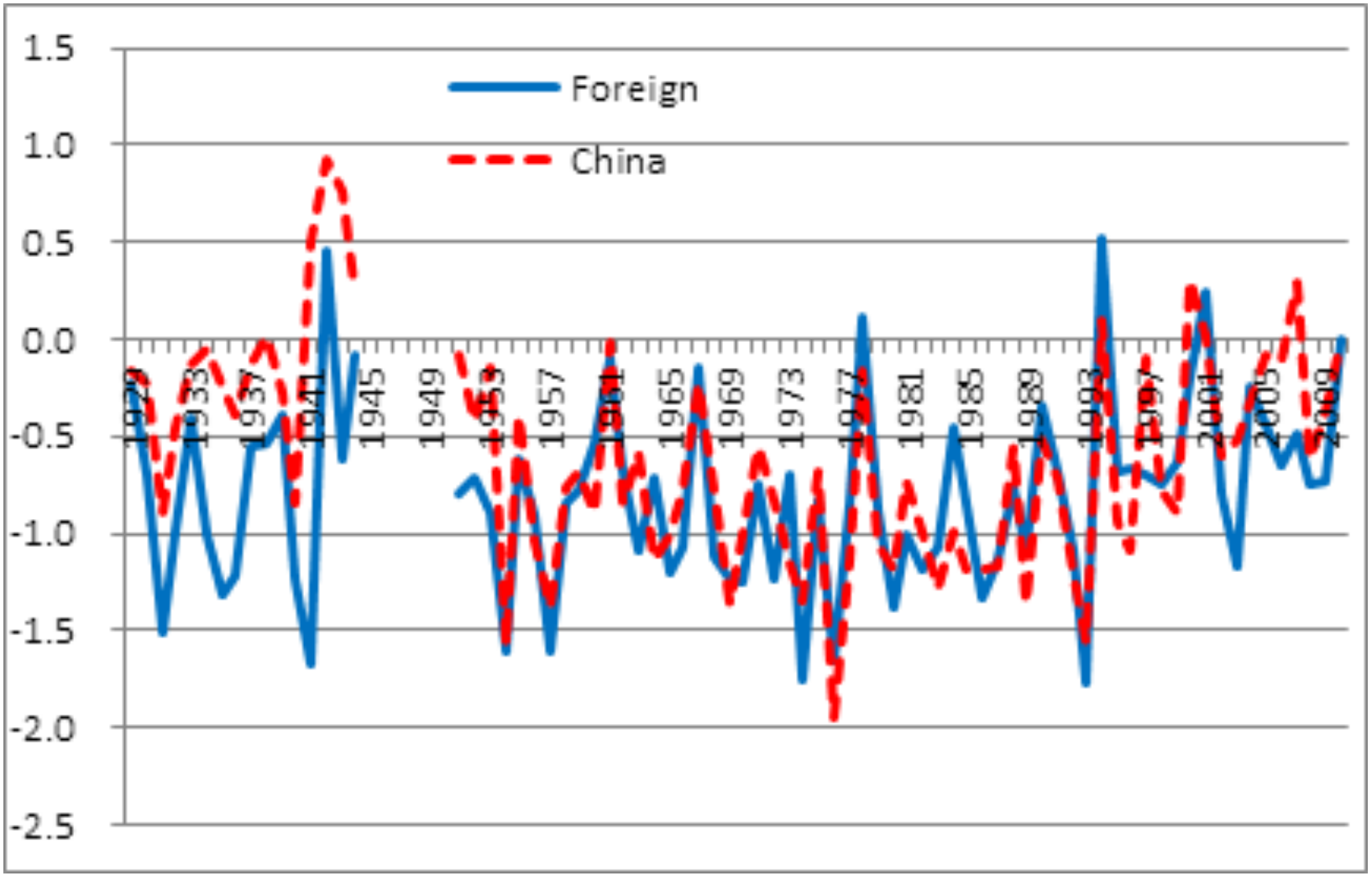


National model: Prob (daily max temp ≥ 35ºC): Year fixed effects (annual average)

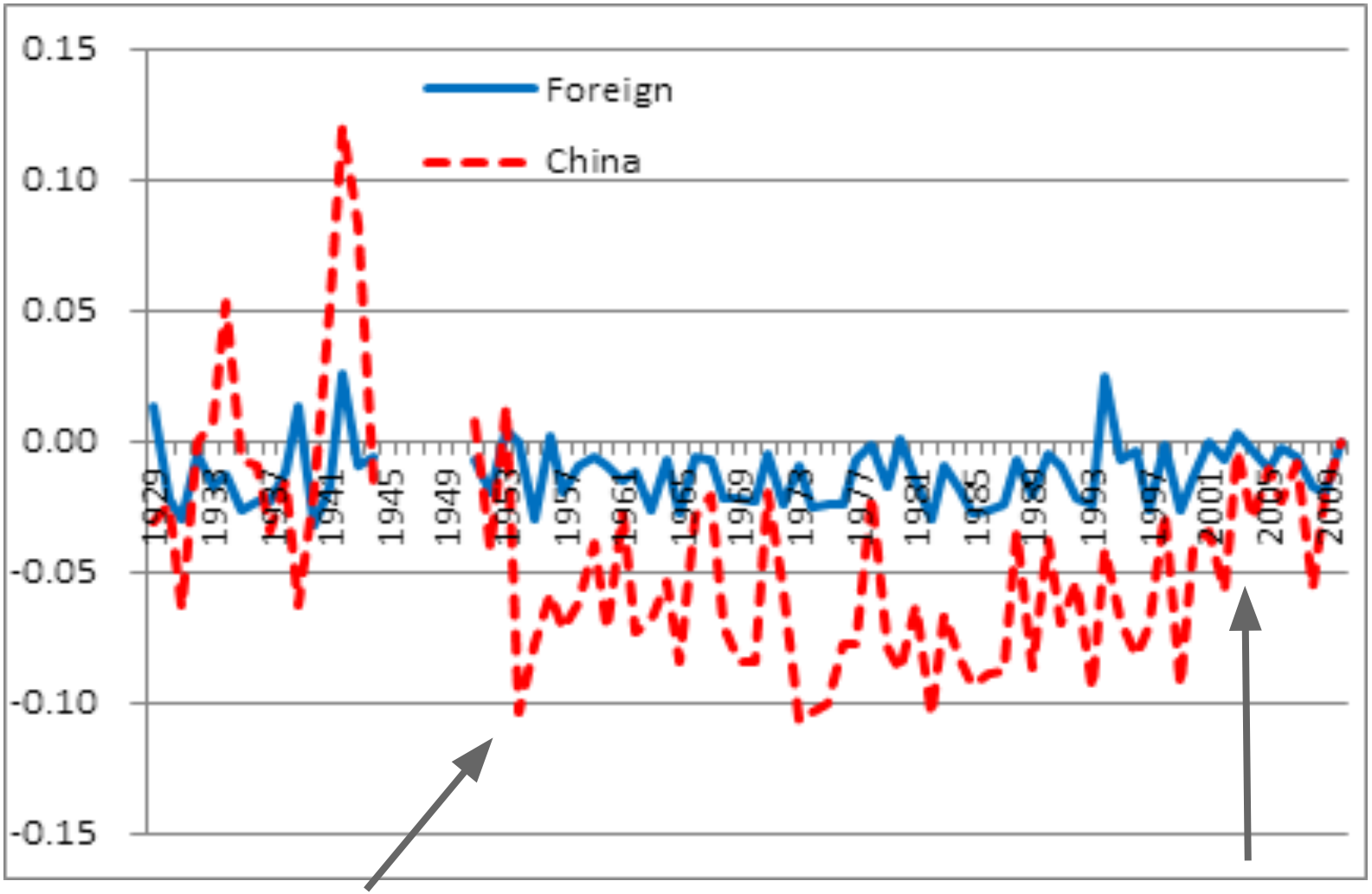


China and foreign series normalized to 2010

National model: Daily max temperature, Jun-Aug: Year fixed effects (annual average)



National model: Prob (daily max temp ≥ 35ºC), Jun-Aug: Year fixed effects (annual average)



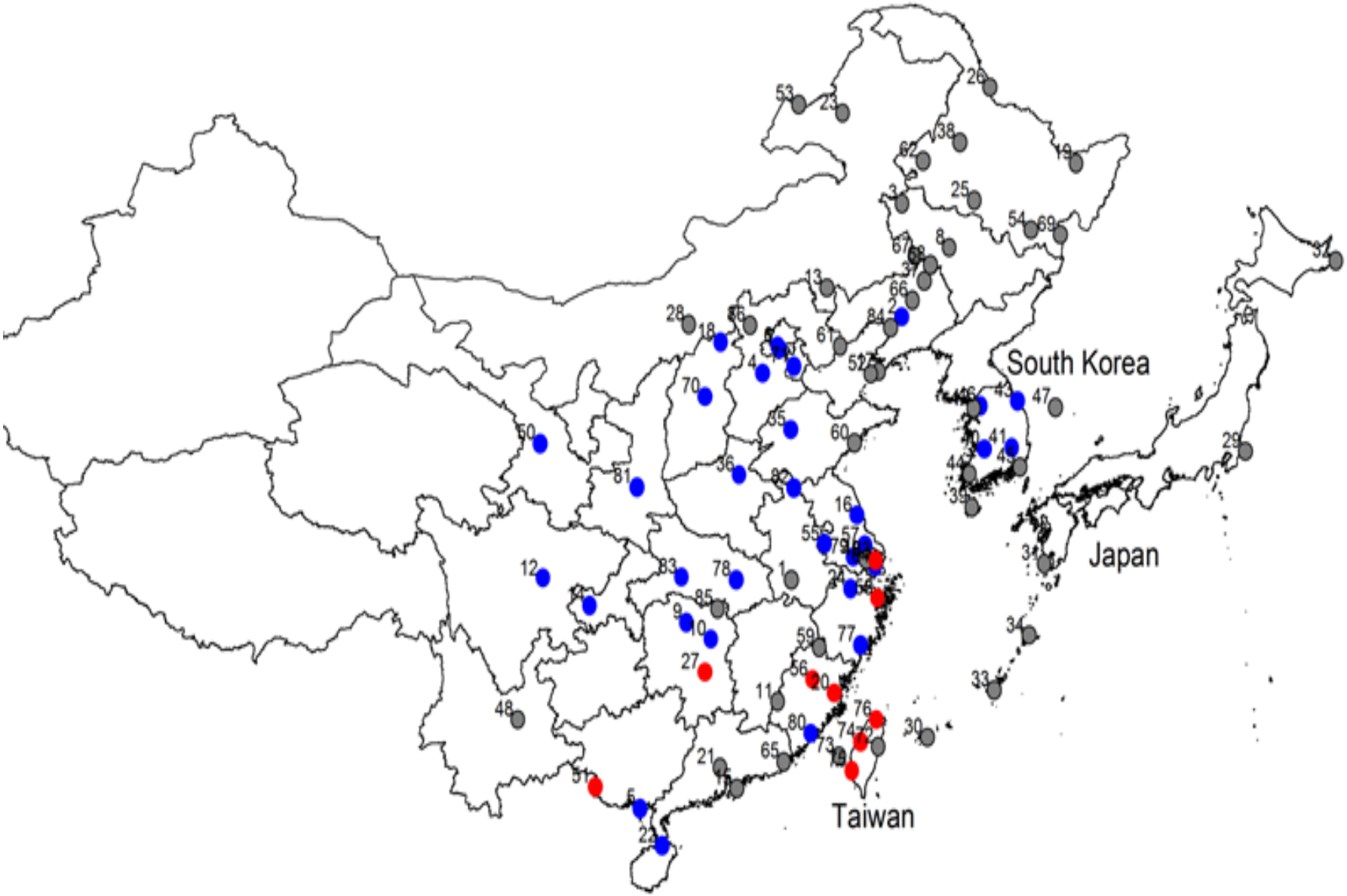
Structural break 1954

Structural break 2001

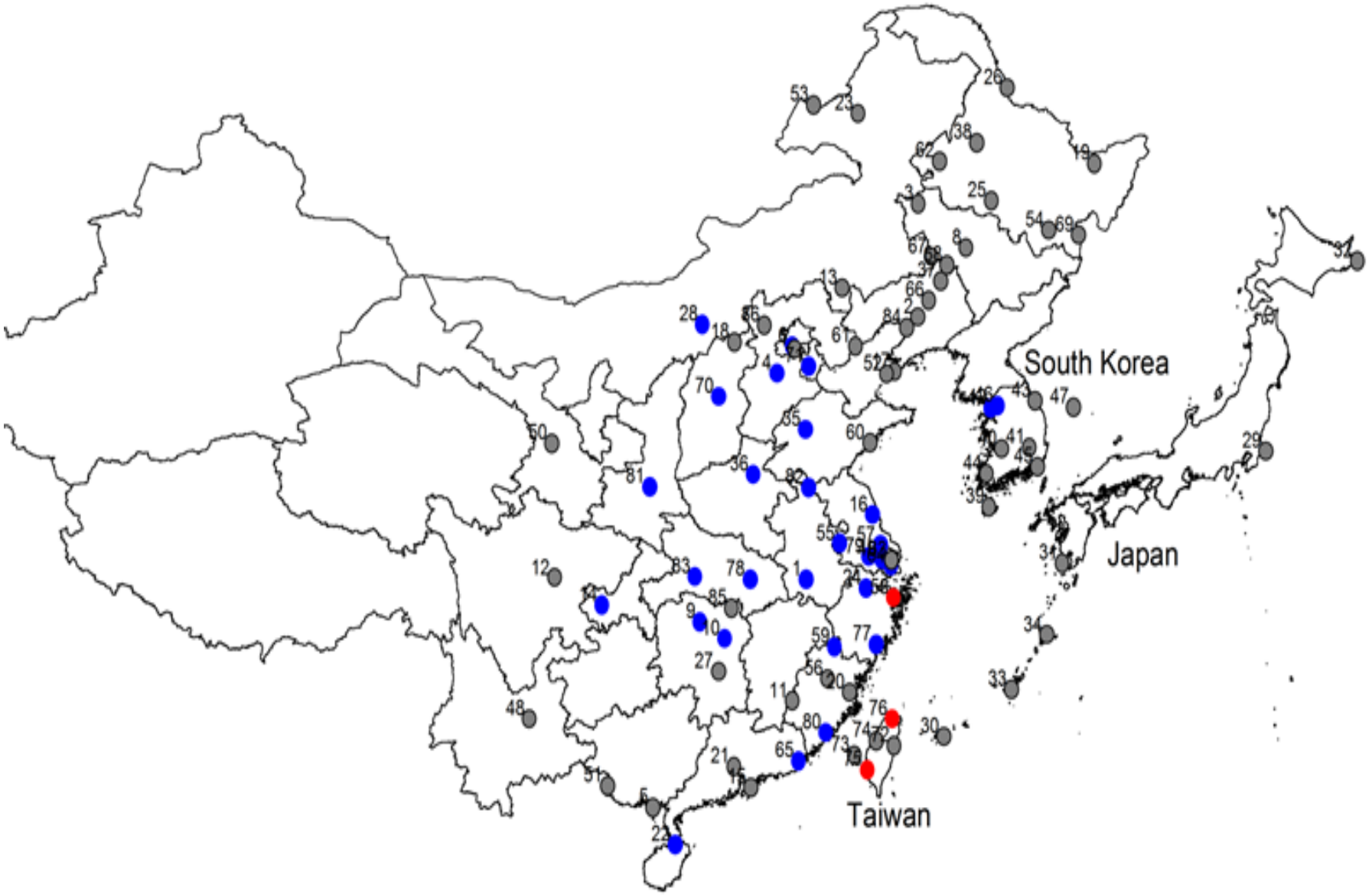
Incremental prob of daily max temp >= 35°C in 1951-2010 relative to 1929-44 in China (relative to foreign)

Jan	0.0004	0.0027
Feb	-0.0009	0.0028
Mar	-0.0004	0.0027
Apr	-0.0030	0.0028
May	-0.0106	0.0028
Jun	-0.0454	0.0028
Jul	-0.0477	0.0028
Aug	-0.0482	0.0027
Sep	-0.0109	0.0028
Oct	-0.0011	0.0028
Nov	-0.0003	0.0028
Dec	0.0000	.

Prob of daily max temp ≥ 35°C in July, 1954-2010 vis-a-vis 1929-1944



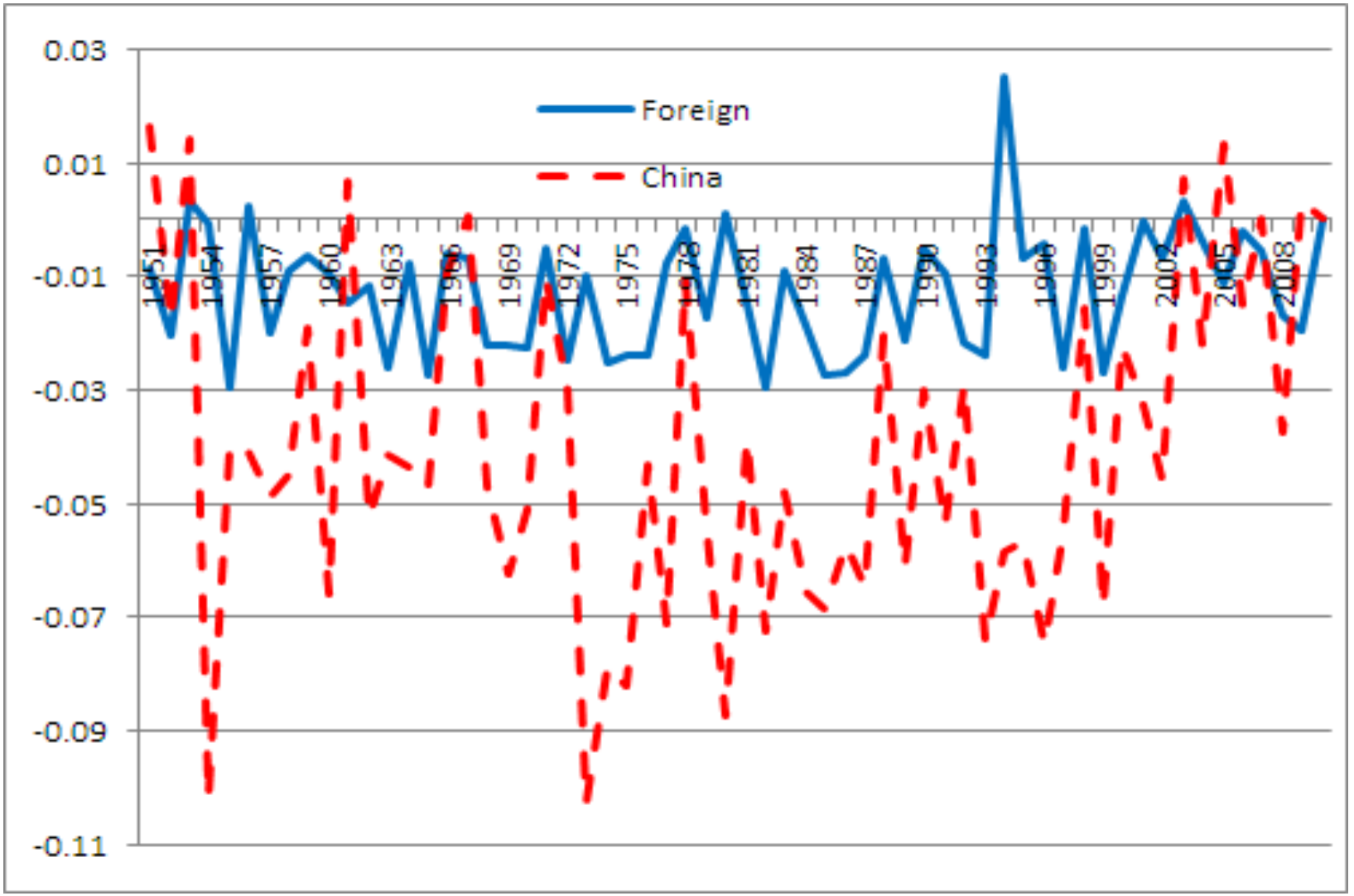
Prob of daily max temp ≥ 35°C in August, 1954-2010 vis-a-vis 1929-1944



Robustness checks

- Sample
  - Distance ≤ 5km, number of years ≥ 7
  - Homogeneous: 36 China + 21 foreign stations, all years, 1951-2010
- Measurement
  - Pre-1950 observations clustered at .0 and .5:
  - Alternative benchmark: Probability of daily maximum temperature $\geq$ 34.9ºC
- Specification: Week fixed effects
- Estimation method
  - Logit
  - Probit

Homogeneous sample, Jun-Aug, 1951-2010



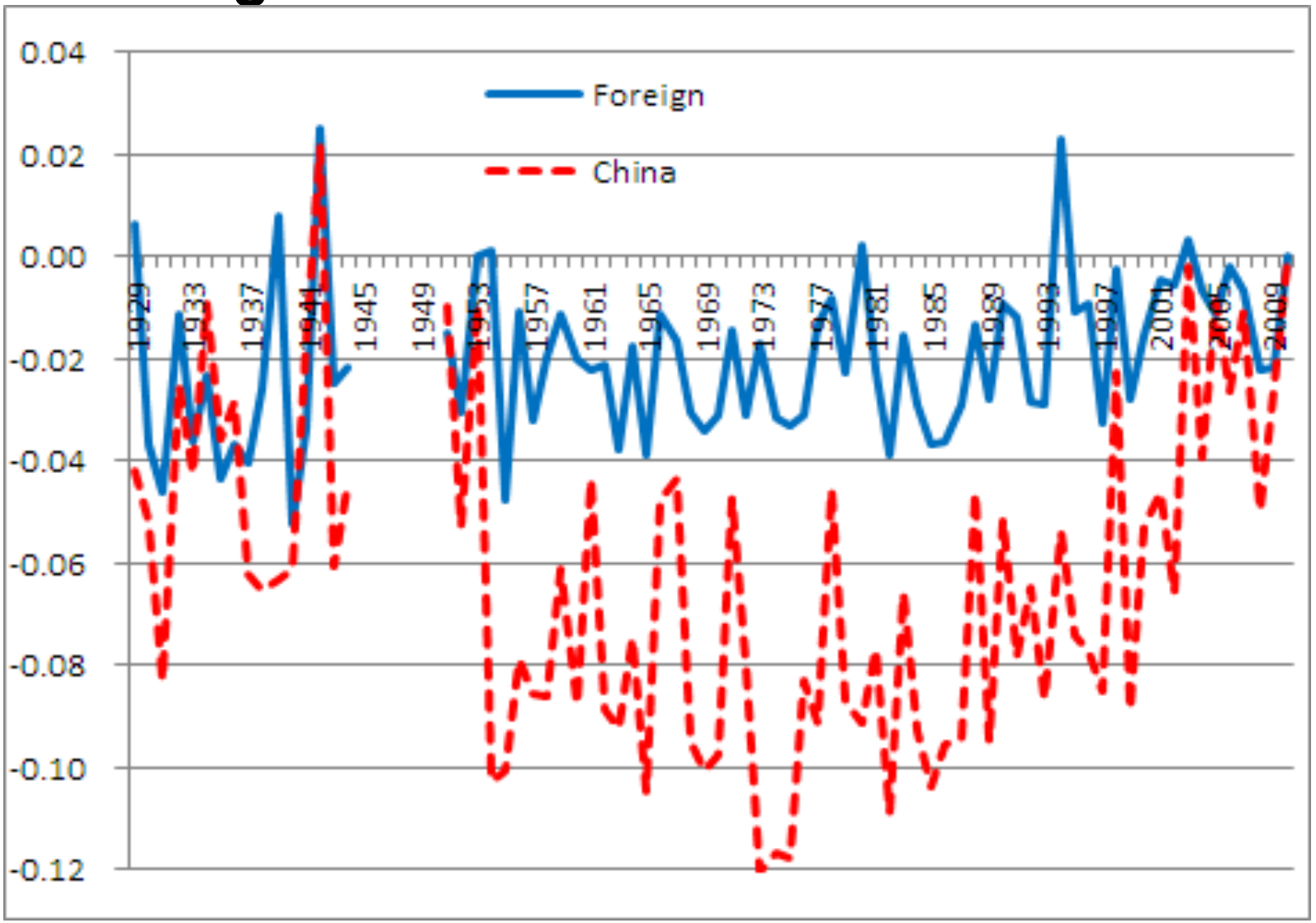
Outline

- Data
- Method
- Results
- Explanations
  - Aerosol effects
  - Evolution of climate: Coastal/inland
  - Urbanization
  - Technology, standards, and procedures
- Hot weather policy
- Discussion

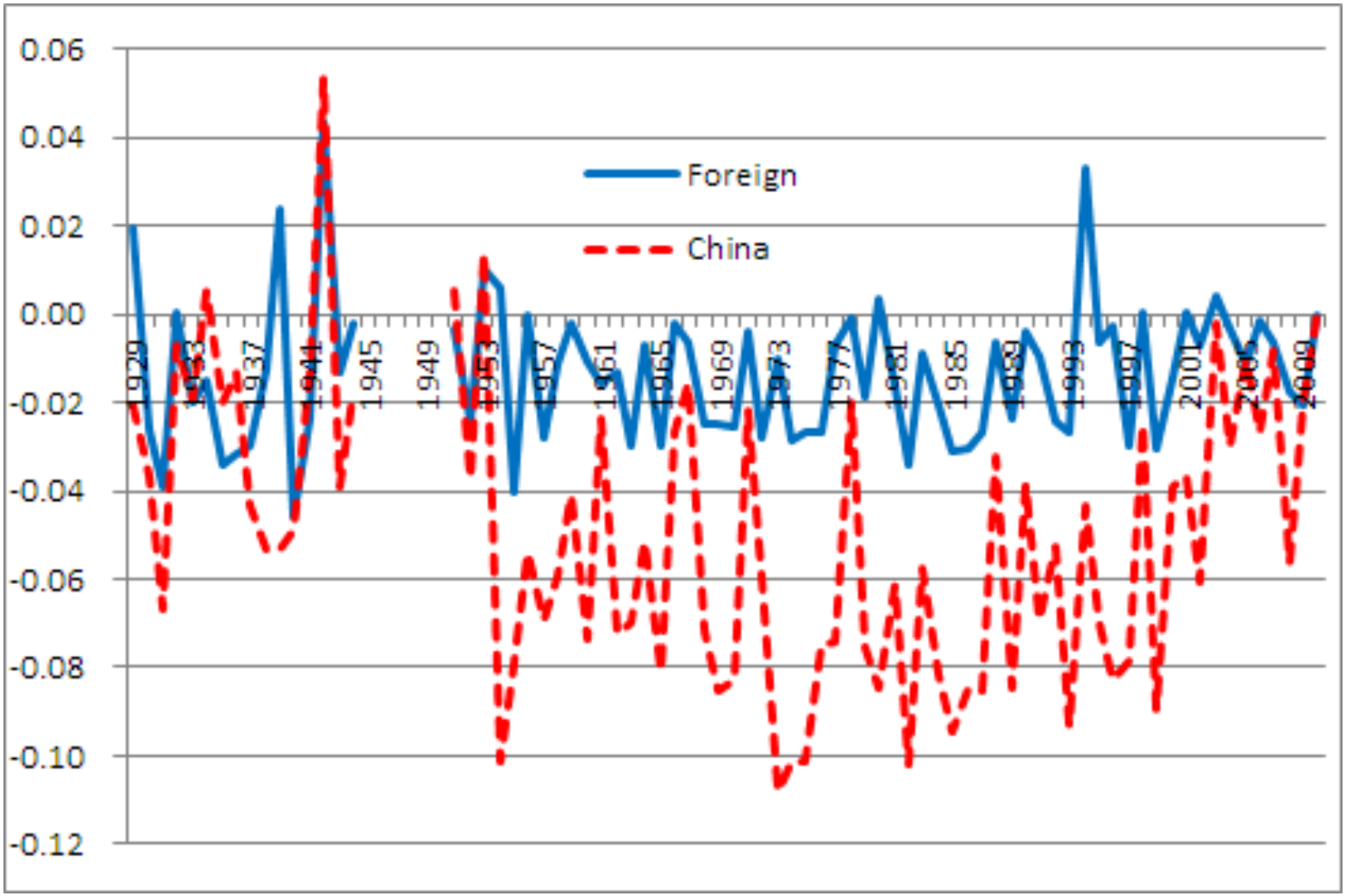
Aerosol effects

- Atmospheric aerosols
  - Directly scatter and absorb solar radiation
  - Indirectly provide nuclei for condensation of clouds or formation of ice
- Sources of aerosols
  - Cloud
  - Water vapour
  - Humidity
  - Dust
  - Emissions -- increase with China’s economic growth
- Overall measure: daily sunshine hours
  - Limited data => smaller sample

Prob of daily max temp ≥ 35°C: Including sunshine hours



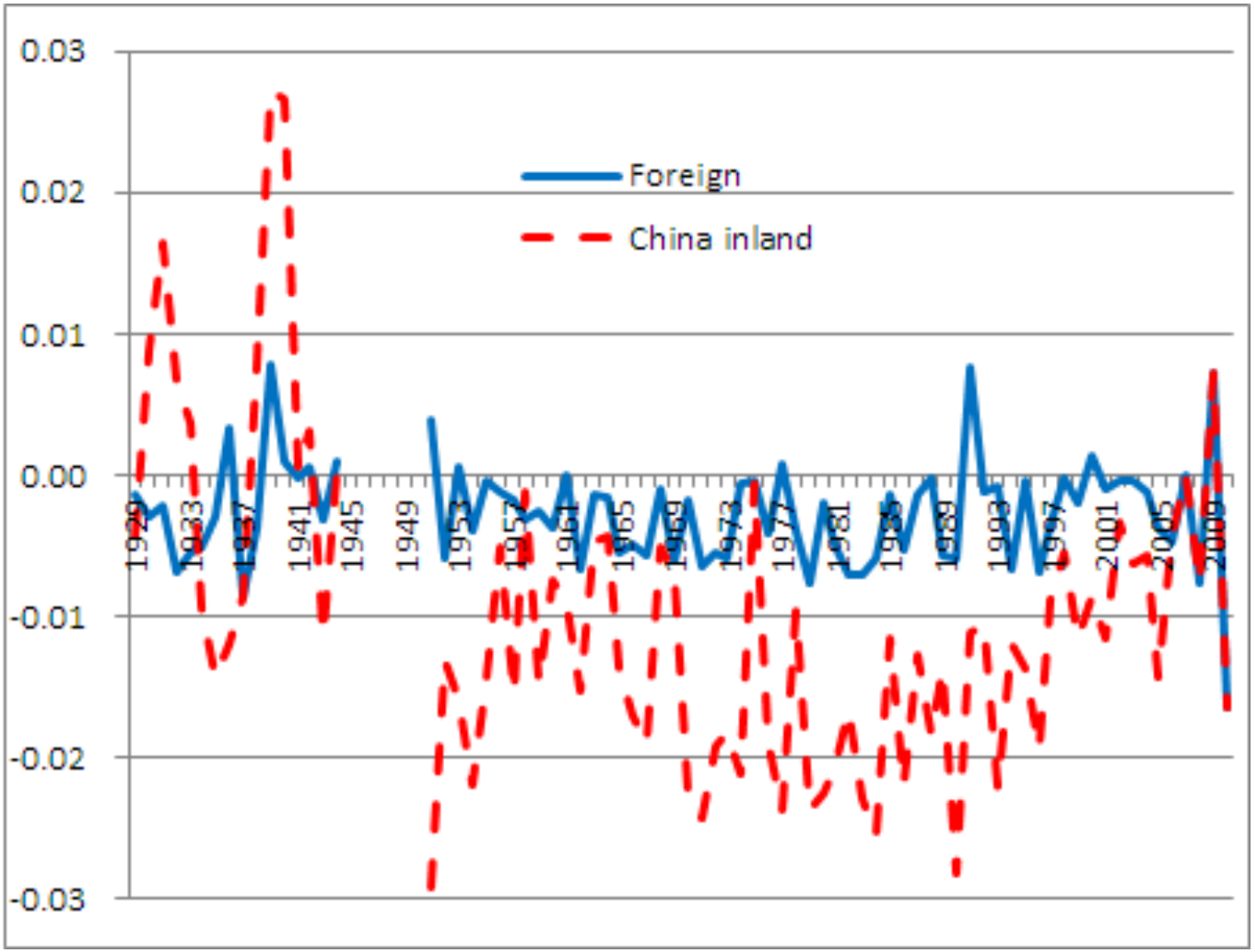
Prob of daily max temp ≥ 35°C: Sunshine sample without sunshine covariate



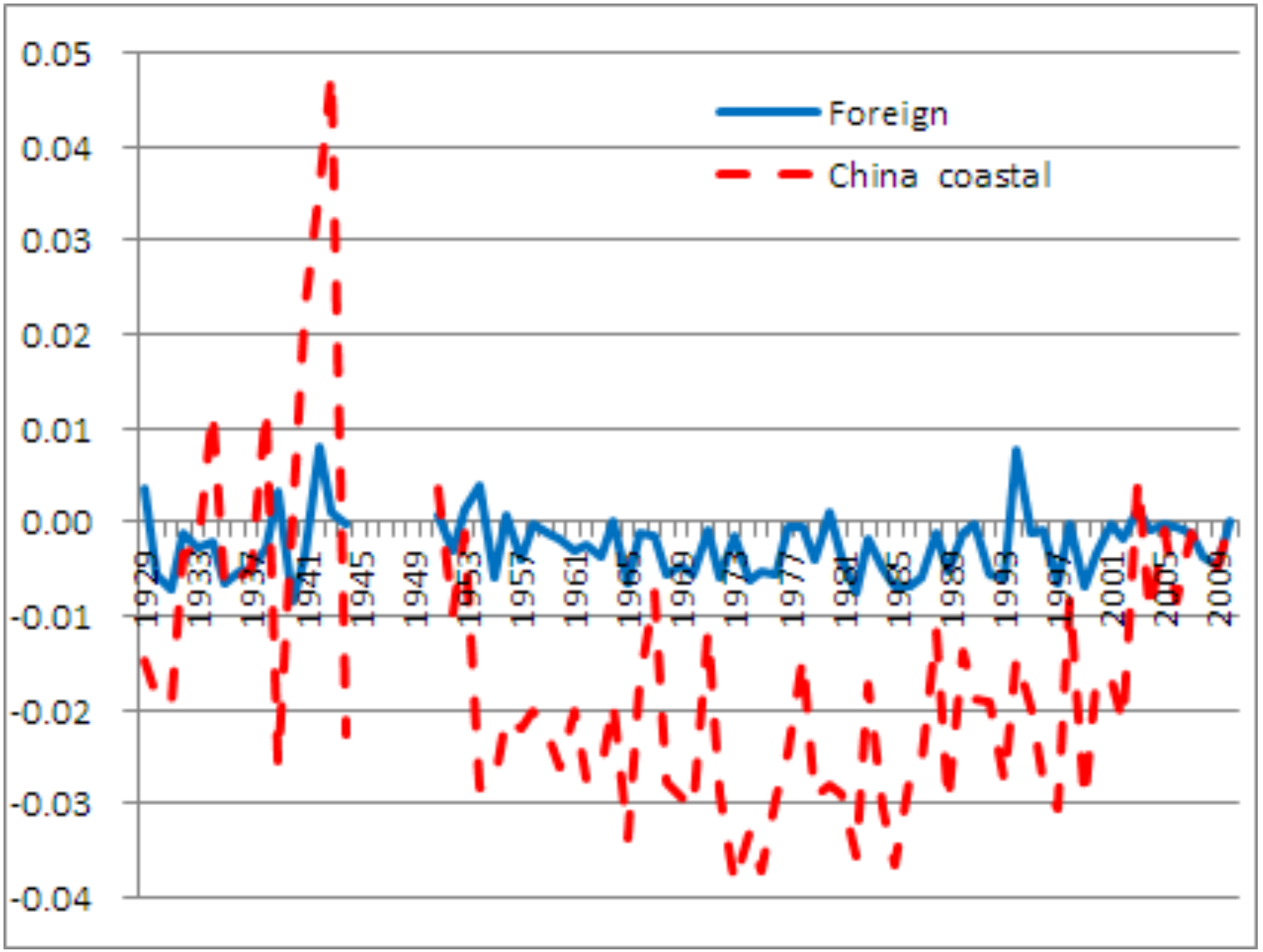
Evolution of climate: Inland/coastal

- Permanent regional differences -- inland climate more extreme
  - Absorbed by station fixed effects
- Conjecture -- time-varying regional differences:
  - Perhaps climate of inland China evolved differently from coastal areas (China, Korea, Hong Kong) and offshore islands (Japan, Taiwan)

China inland: Prob of daily max temp ≥ 35°C



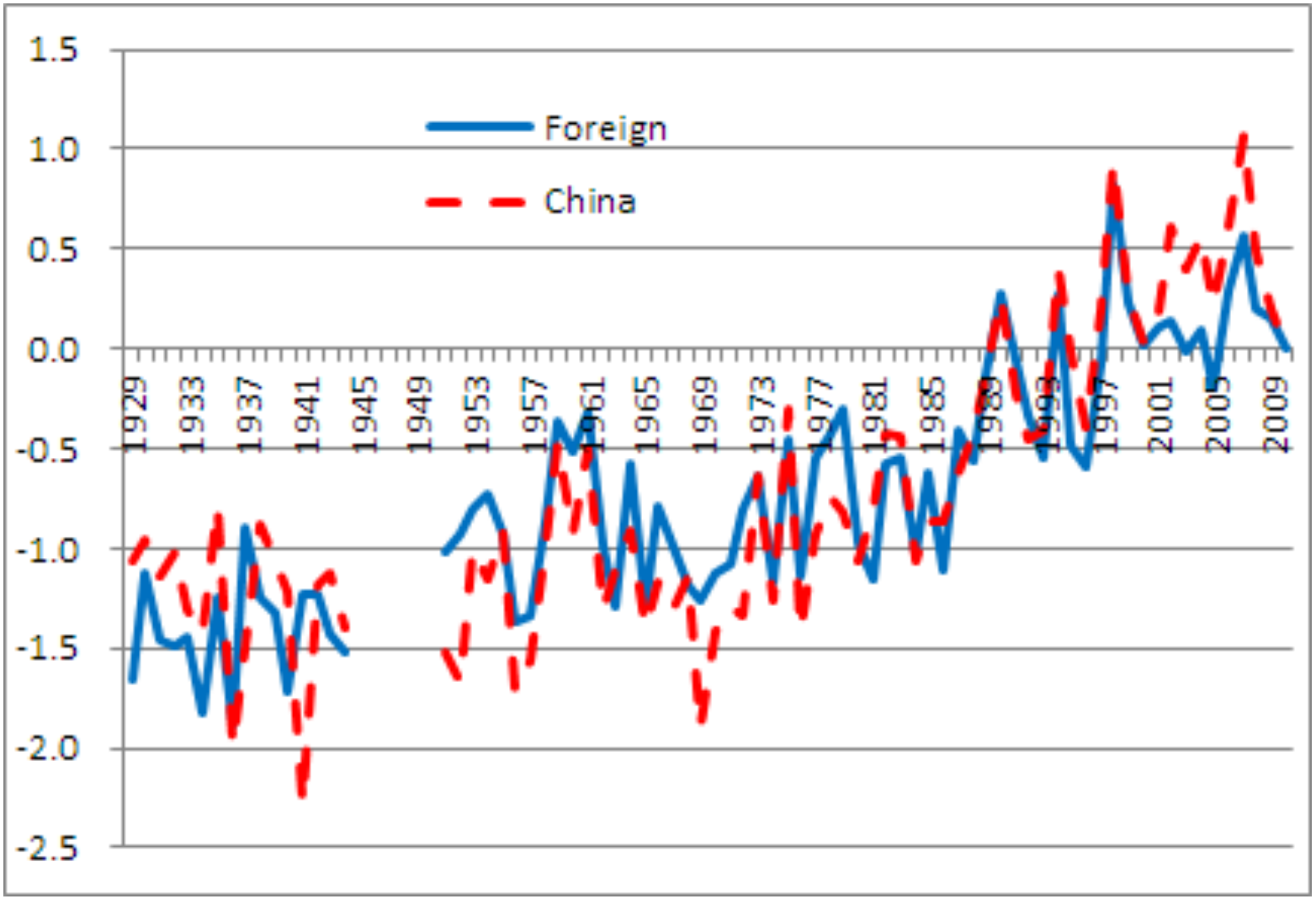
China coastal: Prob of daily max temp ≥ 35°C



Urbanization

- Urbanization affects temperature
  - Building materials absorb and release radiation
  - Surface materials
  - Vegetation
  - Surface moisture
- Southeast China (Zhou et al. PNAS 2004):
  - Warming trend in minimum temperature (+0.116ºC per decade) in winter
    - 10x larger than effect on maximum temperature
    - 21% of overall warming trend in minimum temperature
  - Cooling trend in maximum temperature (-0.016ºC per decade) in winter

Urbanization: Daily minimum temperature



Urbanization

- Urban heat island effect -- strongest effect in *winter*
  - Our results most pronounced in *summer*
- Station-level model: Accounted for by fixed effects for station-year and fixed effects for station-month

Technology, standards, and procedures

- Difficult to explain observed *national* effect on summer extreme temperatures through changes in technology, standards, and procedures
  - General -- change should uniformly affect all recorded temperatures, not asymmetrically affect higher temperatures
  - Movement of stations -- specific to stations, not nation-wide

Technology, standards, and procedures (Kaiser et al. 1993)

But attenuation of extreme temperatures did not reverse around 1960/61

- Temperature
  - Instrument height
    - 1950-53: 1.5 metres
    - 1954-60: 2 metres
    - 1961-onward: 1.5 metres
  - Observation time
    - up to 1950: 2000 hrs Beijing time
    - 1951-53: 2000 hrs Local Standard Time
    - 1954-60: 2000 hrs Local Mean Solar Time
    - 1961-onward: 2000 hrs Beijing time
- Sunshine
  - up to 1953: Jordan Photographic Sunshine Recorder
  - 1954-onward: Campbell-Stokes Sunshine Recorder

Outline

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天有多热，谁说了算

作者：南方周末记者 潘晓凌 黄永明 李邑兰 实习生 李顺 孙宇晨 雷磊

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标签 气象专家 高温 天气预报

■预报温度为何总是低于实际感受？

■高温预警，这是不是一个纯粹的科学问题？

■“天气预报就是不上40℃”，这一传言有无根据？

■在酷热的上海，中国气象局下属中国天气网为什么记载6至8月连续三月无高温？

气象专家：高温预报是测量出来的，也是“商量”出来的

Government policy



- 1954: Iron and Steel Bureau: “Report on hot weather measures”
  - Temperatures in workshop must not exceed 30ºC
- 1956: State Council: “Notice to accelerate implementation of summer hot weather measures”
  - *Temperatures in some areas of Southern China have exceeded 100-year records*
  - In extremely hot weather and remedial measures not possible, consider temporary stoppage of work
  - No overtime work during hot weather

Government policy



- 1960: Ministry of Health, Ministry of Labor, and National Federation of Trade Unions: Interim Regulation on Hot Weather Work
- Provincial governments progressively introduced detailed regulations on hot weather work
  - 1963: Guangzhou
  - 1994: Shenzhen
  - 2005: Hunan, Jiangsu
  - 2007: Chongqing, Hubei, Beijing

Government policy



- 2007: Additional measures
- 2012: State Administration of Work Safety, Ministry of Health, Ministry of Human Resources and Social Security, and All China Federation of Trade Unions: Final Regulation No. 89 of 2012

Final Regulation, No. 89 of 2012

国家安全生产监督管理总局，卫生部，人力资源和社会保障部，
中华全国总工会

安监总安健〔2012〕89号: 防暑降温措施管理办法

第八条 在高温天气期间，用人单位应当按照下列规定，

1. 日最高气温达到40℃以上，应当停止当日室外露天作业；

2. 日最高气温达到37℃以上、40℃以下时，用人单位全天安排劳动者室外露天作业时间累计不得超过6小时，连续作业时间不得超过国家规定，且在气温最高时段3小时内不得安排室外露天作业；

3. 日最高气温达到35℃以上、37℃以下时，用人单位应当采取换班轮休等方式，缩短劳动者连续作业时间，并且不得安排室外露天作业劳动者加班。

Incentives of local government officials

- 天高皇帝远: The sky is high and the emperor is far away
- Pre-1978 reform
  - Local officials required to meet central planning targets
- Post-1978 reform
  - Government depends on industrial enterprises for revenues and other support
  - Local officials evaluated by economic performance of their territory (Li and Zhou 2005)

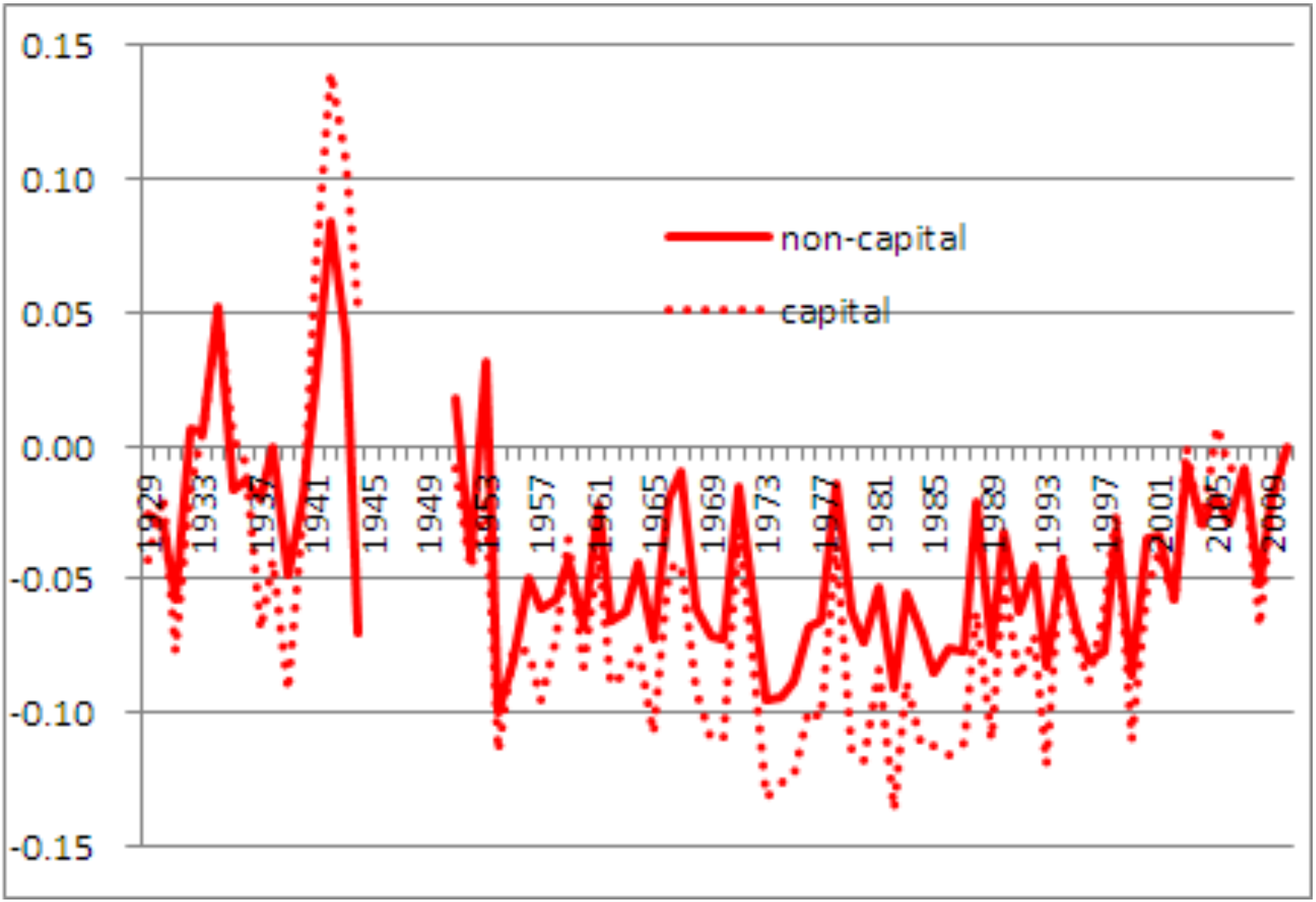
Weather reporting

- 1956: “Temperatures in some areas of Southern China have exceeded 100-year records” (State Council)
  - All stations: Jun-Aug temperatures *lower* in 1956 than 1929-44
  - Conjecture: Re-writing of historical weather statistics
- 2010: Li Kai-le, ex senior technical officer, Guangdong Province Meteorological Office: “Some officials worry about the cost and disruption of warnings, and ask for a more conservative forecast” (Nanfang.com, 2010)

Compliance with hot weather regulations

- 1954: “some enterprises did not truthfully report heat stroke incidents and workshop temperature” (Iron and Steel)
- 1956: “some enterprises did not prepare measures for hot weather work in summer” (State Council)
- 1956: Wenzhou Steel Factory concealed industrial accidents, reported 8 instead of 21 in August (“Factory manager Zheng Kezhong did not respect worker safety”)

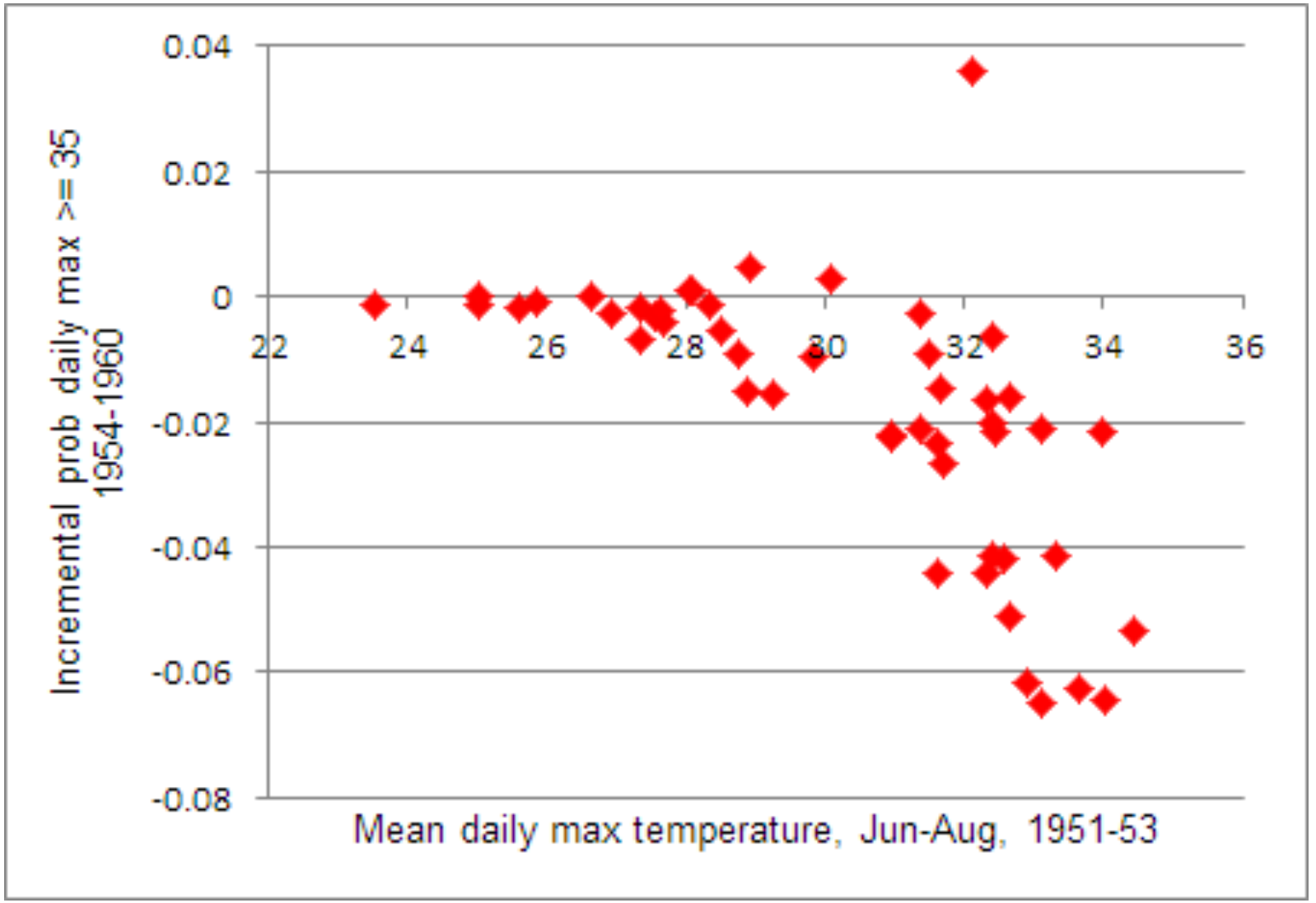
Prob of daily max temp ≥ 35°C, Jun-Aug: Provincial capitals vis-a-vis other stations



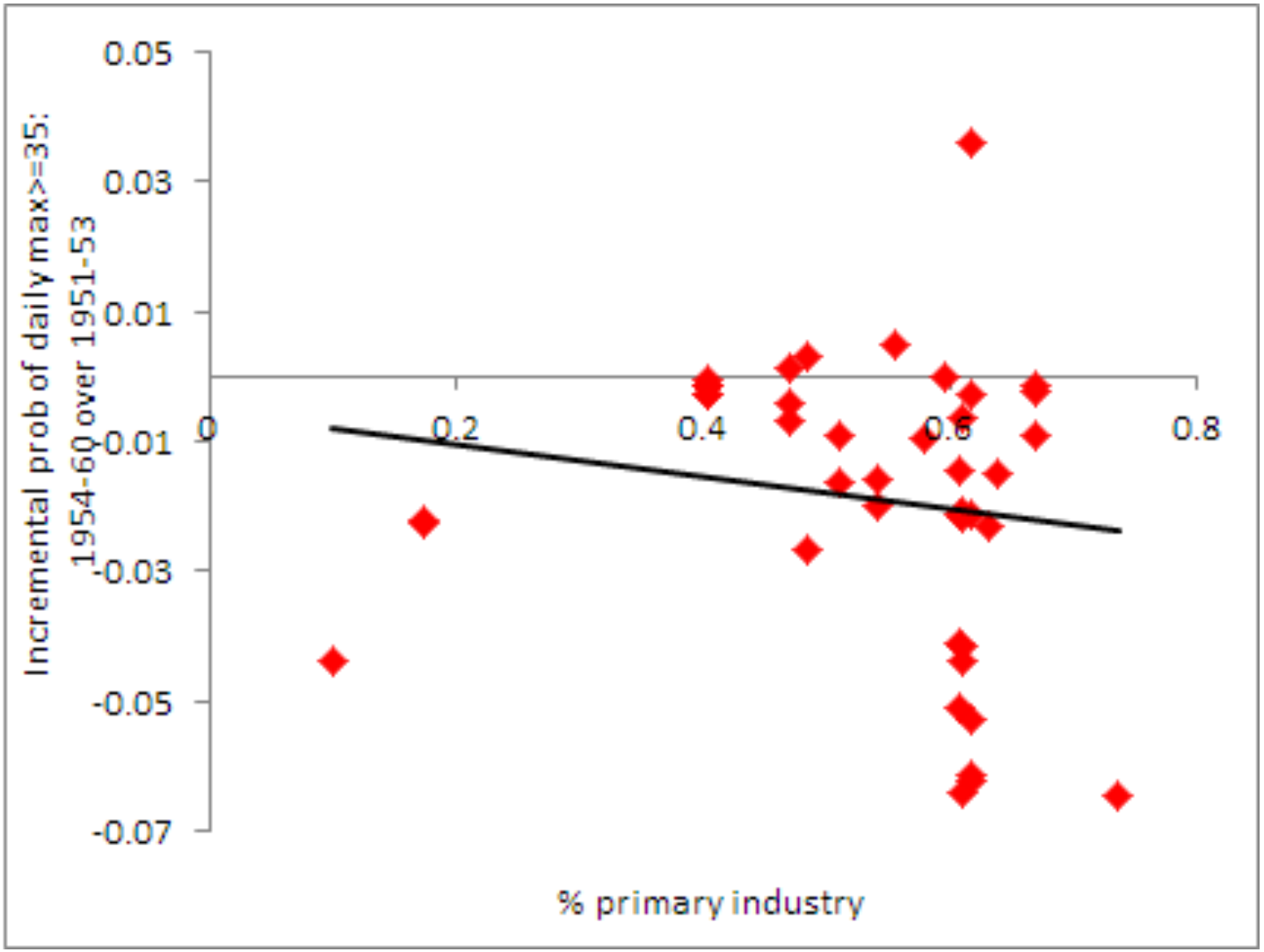
Structural break #1:
Lower frequency of extreme temp, 1954-60

- Average daily maximum temperature, Jun-Aug, 1951-53
-
- Economic structure

Lower frequency of extreme temp, 1954-60: Average summer extreme temp, 1951-53



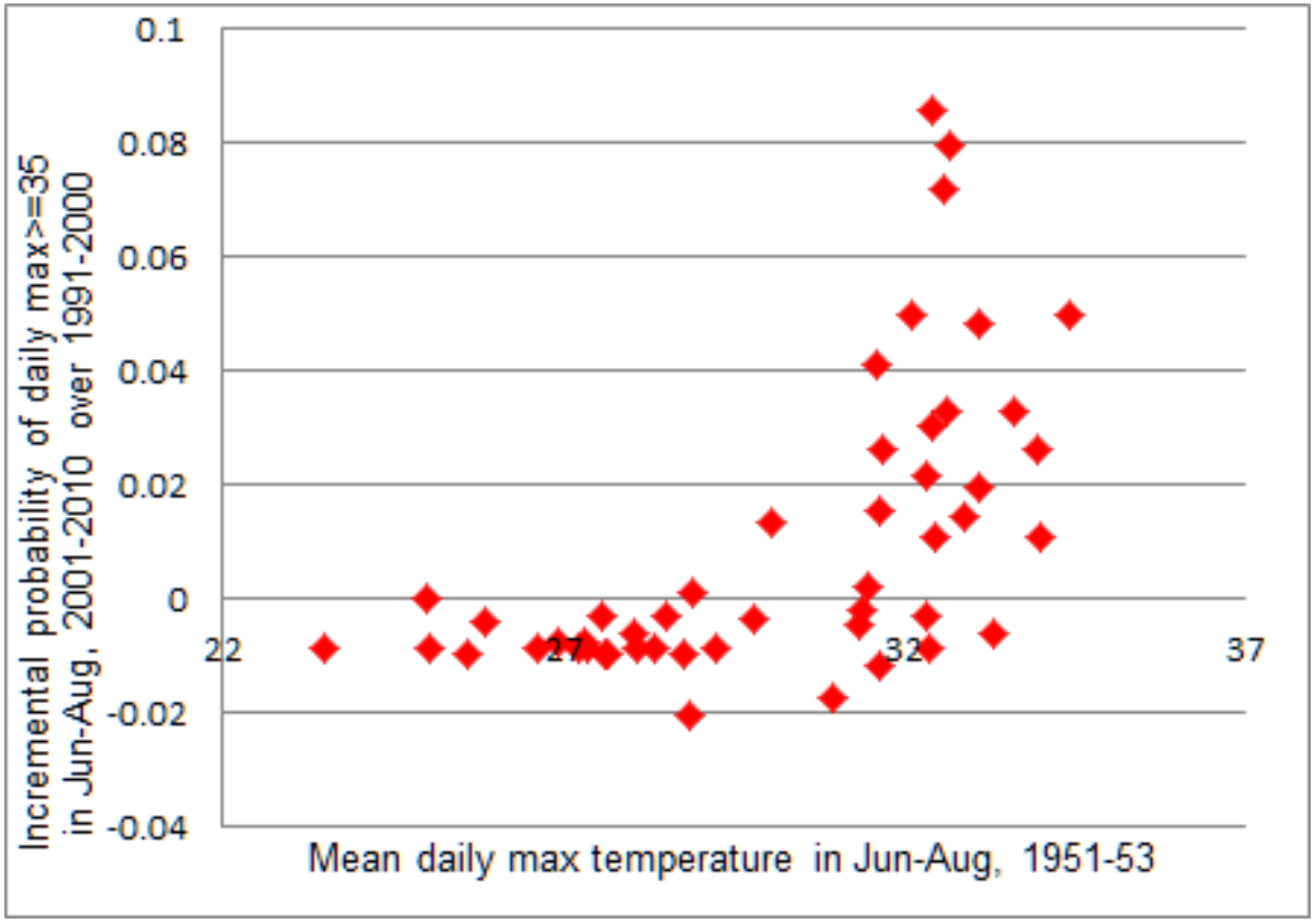
Lower frequency of extreme temp, 1954-60: Economic structure



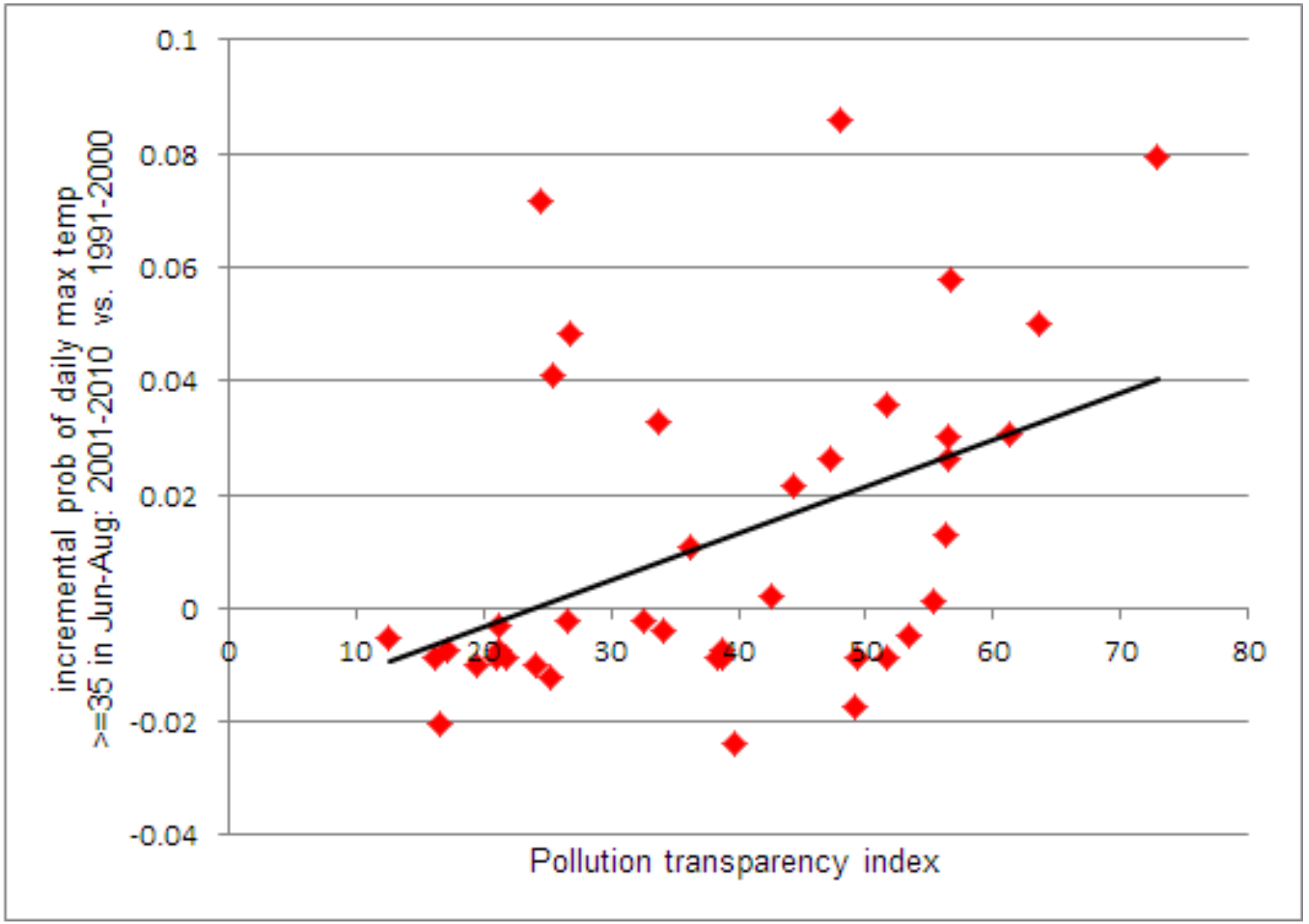
Structural break #2:
Higher frequency of extreme temp, 2001-10

- Average daily maximum temperature, Jun-Aug, 1951-53
- Pollution Information Transparency Index, 2008-onward
  - Institute of Public & Environmental Affairs (China) and Natural Resources Defense Council
- Economic structure: Percent of employment in construction

Higher frequency of extreme temp, 2001-10: Mean daily max temperature, 1951-53



Higher frequency of extreme temp, 2001-10: Pollution Information Transparency Index



Higher frequency of extreme temp, 2001-10: Economic structure



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Implications: Welfare

- Welfare and health
  - Businesses -- illegal in China for any organization other than CMA to publish weather
  - Individuals -- can monitor hot weather themselves

Implications: Climate studies

- Summer extreme temperatures affected by
  - Global trends
  - Aerosol effects -- natural and anthropogenic
  - Under-reporting?